CMSAF AVHRR-based CDR of TOA radiative fluxes (CLARA-A3): preliminary results and validation

Tom Akkermans, Nicolas Clerbaux

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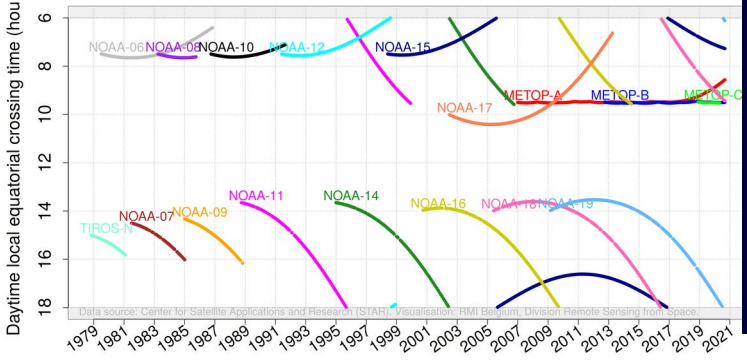
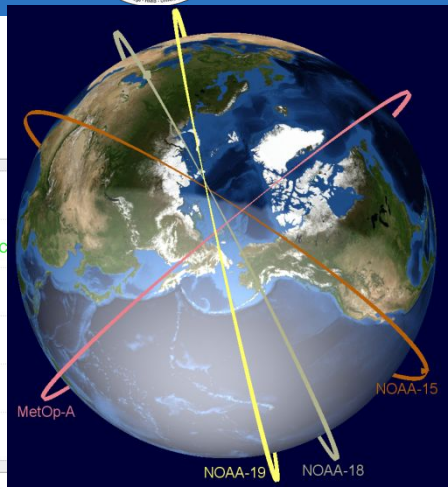
1. Introduction

- **What is CLARA?** "**C**M SAF c**L**oud, **A**lbedo and **RA**diation dataset from AVHRR data" (≈similar to Patmos-X):
  - Polar orbiting : NOAA and MetOp
  - FCDR from NOAA (Heidinger,2010)
  - L3 products on 0.25°x0.25°
  - Currently released versions:
    - CLARA-A1 (1982-2009)
    - CLARA-A2 (1982-2015)





- **Some of the modifications in the upcoming version CLARA-A3:**
  - Inclusion of the AVHRR-1 sensor (TIROS-N, NOAA-6,-8,-10): extension of time range to 1979-2020, which is 42 years
  - Updated FCDR: new calibration for visible channels (latest PATMOS-x coefficients)
  - Updated cloud treatment algorithms (NWC SAF / PPS v.2018; Karlsson et al.)
  - Addition of new product "TOA radiative fluxes" → this presentation

2. Methods

Part1 / Part2

Level-2 processing: instantaneous observations

Outgoing Longwave Radiation (OLR)

AVHRR ch4: 11µ | AVHRR ch5: 12µ → FREQUENCY (Hz)

"all-in-one" conversion from narrowband directional brightness temp. to broadband hemispherical flux, based on database with coangular AVHRR-CERES obs.

OLR *[W/m²]* → FREQUENCY (Hz)

Aggregation from orbit to regular CMSAF grid (0.25°x0.25°)

remapped OLR (0.25°)

Reflected Solar Flux (RSF)

AVHRR ch1: 0.6µ | AVHRR ch2: 0.9µ → FREQUENCY (Hz)

NB-to-BB regressions based on database with co-angular AVHRR-CERES obs.

Broadband reflectance → FREQUENCY (Hz)

ADM's from CERES Ed2B: TRMM, +TERRA for snow/ice

Albedo *[%]* *(hemispherical)* → FREQUENCY (Hz)

Aggregation from orbit to regular CMSAF grid (0.25°x0.25°)

remapped Albedo (0.25°)

Part3

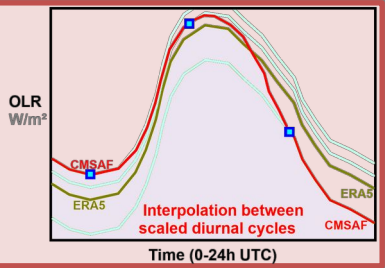
Level-3 processing: daily mean

OLR

ERA5 diurnal cycle OLR

ERA5 diurnal cycle scaled to Level-2 observations, then interpolate :

Daily mean OLR

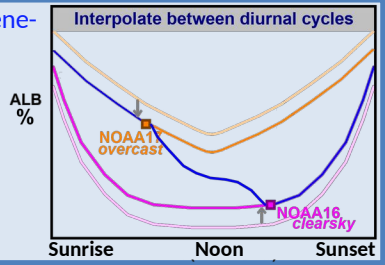


RSF

Method: Young et al. ('98): match scene-dependent average diurnal cycle to observations, then interpolate

Convert albedo to flux

Daily mean RSF [W/m²]



P4

Level-3b processing

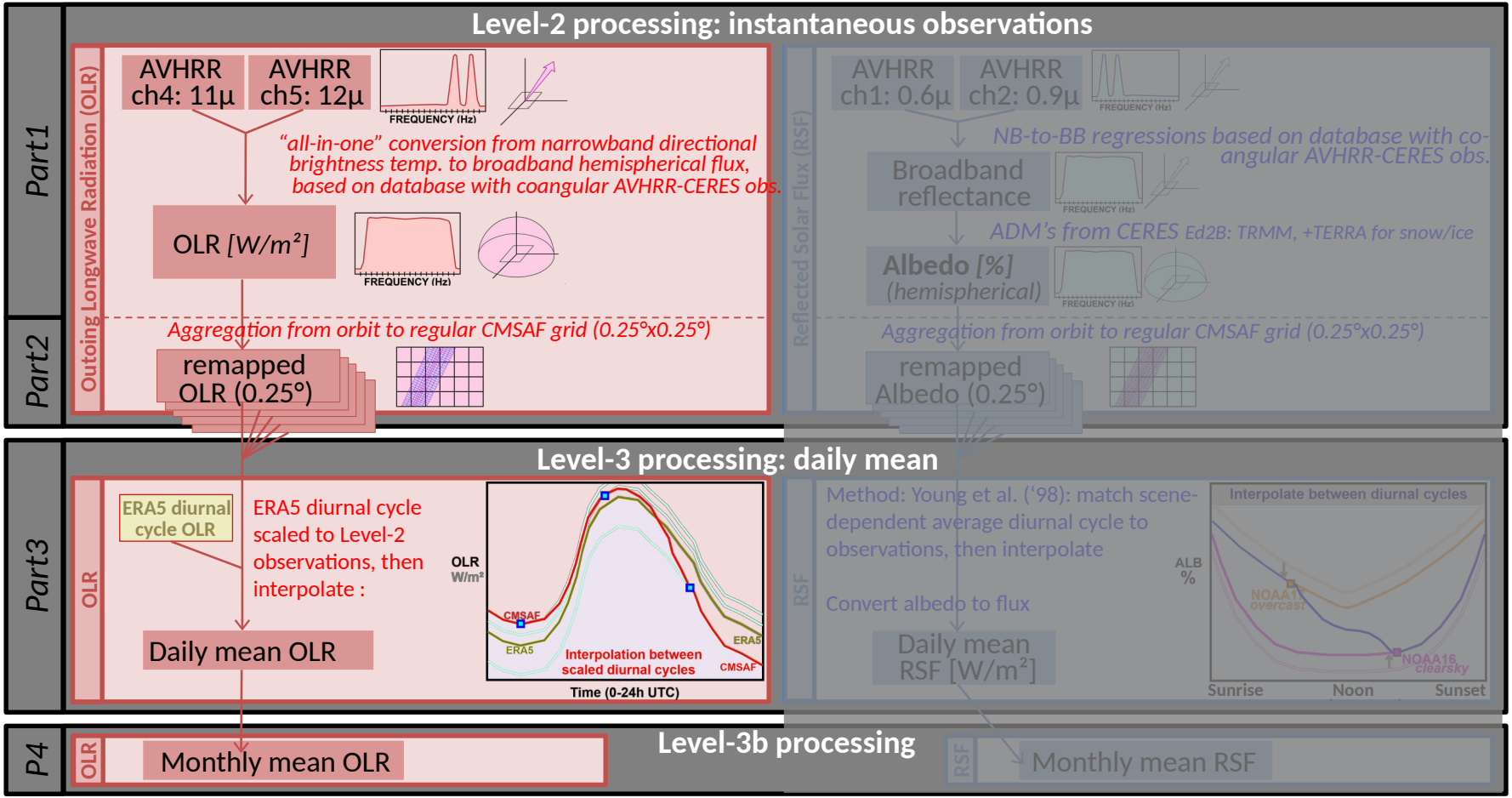
OLR

Monthly mean OLR

RSF

Monthly mean RSF

2. Methods


Part1
Part2
Part3
P4
Level-2 processing: instantaneous observations
Outoing Longwave Radiation (OLR)
AVHRR ch4: 11µ
AVHRR ch5: 12µ
FREQUENCY (Hz)
"all-in-one" conversion from narrowband directional brightness temp. to broadband hemispherical flux, based on database with coangular AVHRR-CERES obs.
OLR [W/m²]
Aggregation from orbit to regular CMSAF grid (0.25°x0.25°)
remapped OLR (0.25°)
Reflected Solar Flux (RSF)
AVHRR ch1: 0.6µ
AVHRR ch2: 0.9µ
NB-to-BB regressions based on database with co-angular AVHRR-CERES obs.
Broadband reflectance
ADM's from CERES Ed2B: TRMM, +TERRA for snow/ice
Albedo [%] (hemispherical)
Aggregation from orbit to regular CMSAF grid (0.25°x0.25°)
remapped Albedo (0.25°)
Level-3 processing: daily mean
OLR
ERA5 diurnal cycle OLR
ERA5 diurnal cycle scaled to Level-2 observations, then interpolate :
Daily mean OLR
OLR W/m²
CMSAF
ERA5
Interpolation between scaled diurnal cycles
Time (0-24h UTC)
RSF
Method: Young et al. ('98): match scene-dependent average diurnal cycle to observations, then interpolate
Convert albedo to flux
Daily mean RSF [W/m²]
Interpolate between diurnal cycles
ALB %
NOAA17 overcast
NOAA16 clearsky
Sunrise
Noon
Sunset
Level-3b processing
OLR
Monthly mean OLR
RSF
Monthly mean RSF

2. Methods

Level-2 … instantaneous observations

Part1

AVHRR ch4: 11µ | AVHRR ch5

AVHRR ch1: 0.6µ | AVHRR ch2: 0.9µ

NB-to-BB regressions based on database with co-angular AVHRR-CERES obs.

Broadband reflectance

ADM's from CERES Ed2B: TRMM, +TERRA for snow/ice

Albedo *[%]* *(hemispherical)*

Aggregation from orbit to regular CMSAF grid (0.25°x0.25°)

remapped Albedo (0.25°)

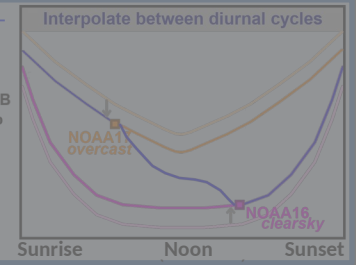
Part3

…ly mean

…ethod: Young et al. ('98): match scene-…pendent average diurnal cycle to …ervations, then interpolate

…vert albedo to flux

Daily mean RSF [W/m²]



P4

OLR

…y mean OLR

Level-3b processing

RSF

Monthly mean RSF

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The Climate Monitoring SAF Outgoing Longwave Radiation from AVHRR

by Nicolas Clerbaux*, Tom Akkermans, Edward Baudrez, Almudena Velazquez Blazquez, William Moutier, Johan Moreels and Christine Aebi

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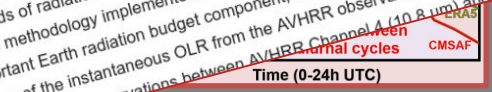
Abstract

Data from the Advanced Very High Resolution Radiometer (AVHRR) have been used to create several long-duration data records of geophysical variables describing the atmosphere and land and water surfaces. In the Climate Monitoring Satellite Application Facility (CM SAF) project, AVHRR data are used to derive the Cloud, Albedo, and Radiation (CLARA) climate data records of radiation components (i.e., surface albedo) and cloud properties (i.e., cloud cover). This work describes the methodology implemented for the additional estimation of the Outgoing Longwave Radiation (OLR), an important Earth radiation budget component, that is consistent with the other CLARA variables. A first step is the estimation of the instantaneous OLR from the AVHRR observations. This is done by regressions on a large database of collocated observations between AVHRR Channel 4 (10.8 µm) and 5 (12 µm) and



2. Methods

Level-2 processing: instantaneous observations

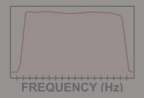
Part1

Outgoing Longwave Radiation (OLR)

AVHRR ch4: 11µ | AVHRR ch5: 12µ

"all-in-one" conversion from narrowband directional brightness temp. to broadband hemispherical flux, based on database with coangular AVHRR-CERES obs.

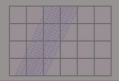
OLR *[W/m²]*



Part2

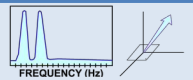
Aggregation from orbit to regular CMSAF grid (0.25°x0.25°)

remapped OLR (0.25°)



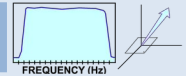
Reflected Solar Flux (RSF)

AVHRR ch1: 0.6µ | AVHRR ch2: 0.9µ



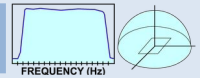
NB-to-BB regressions based on database with co-angular AVHRR-CERES obs.

Broadband reflectance



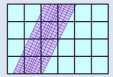
ADM's from CERES Ed2B: TRMM, +TERRA for snow/ice

Albedo *[%]* *(hemispherical)*



Aggregation from orbit to regular CMSAF grid (0.25°x0.25°)

remapped Albedo (0.25°)



Level-3 processing: daily mean

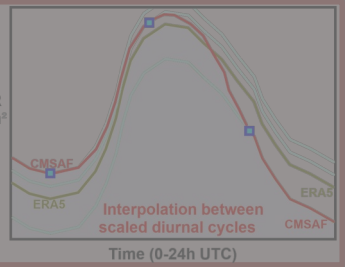
Part3

OLR

ERA5 diurnal cycle OLR

ERA5 diurnal cycle scaled to Level-2 observations, then interpolate :

Daily mean OLR

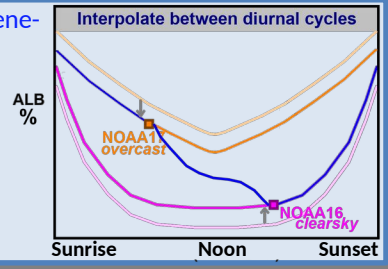


RSF

Method: Young et al. ('98): match scene-dependent average diurnal cycle to observations, then interpolate

Convert albedo to flux

Daily mean RSF [W/m²]



Level-3b processing

P4

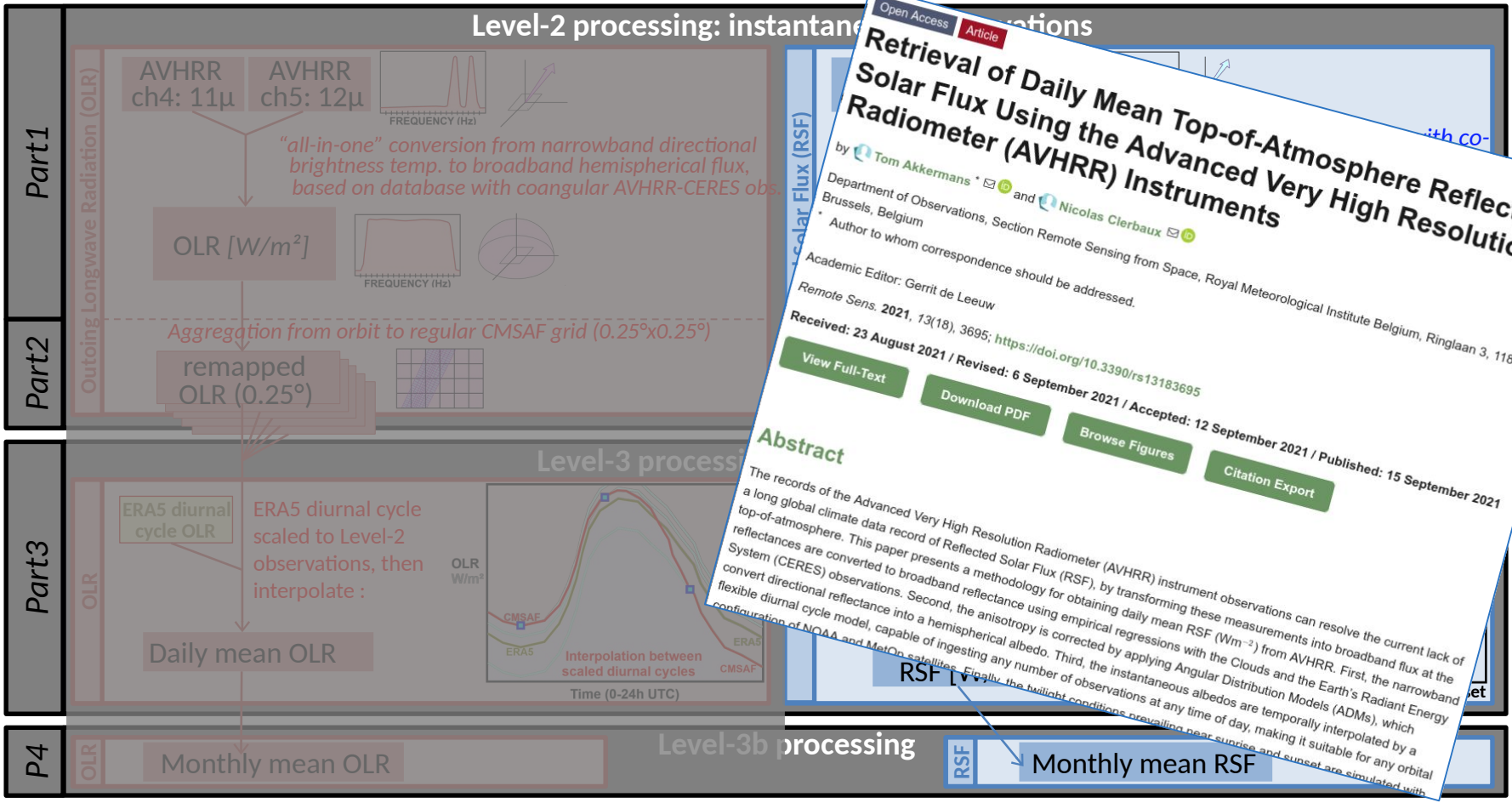
OLR

Monthly mean OLR

RSF

Monthly mean RSF

2. Methods



Open Access Article

Retrieval of Daily Mean Top-of-Atmosphere Reflected Solar Flux Using the Advanced Very High Resolution Radiometer (AVHRR) Instruments

by Tom Akkermans * and Nicolas Clerbaux
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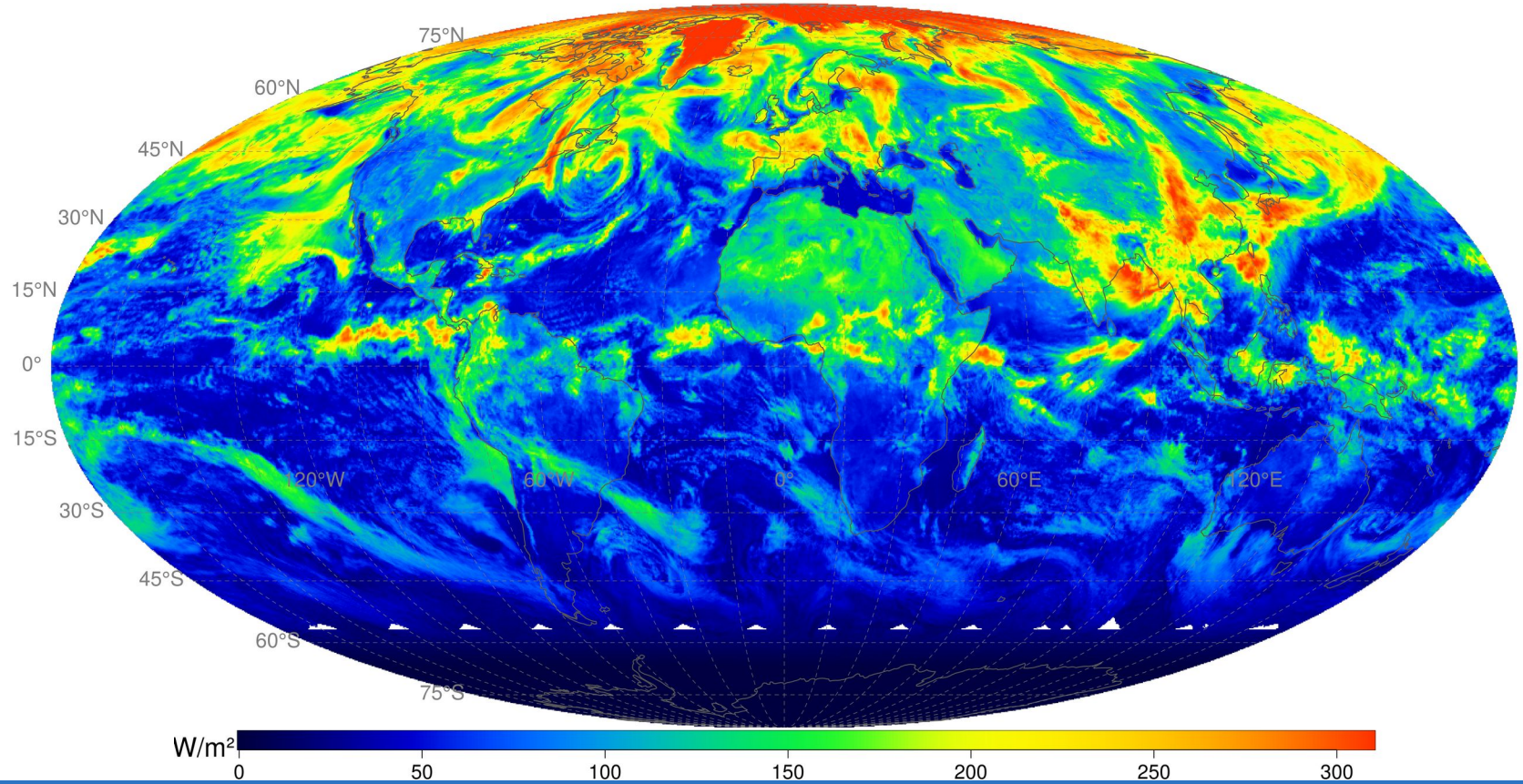
Abstract

The records of the Advanced Very High Resolution Radiometer (AVHRR) instrument observations can resolve the current lack of a long global climate data record of Reflected Solar Flux (RSF), by transforming these measurements into broadband flux at the top-of-atmosphere. This paper presents a methodology for obtaining daily mean RSF (Wm^{-2}) from AVHRR. First, the narrowband reflectances are converted to broadband reflectance using empirical regressions with the Clouds and the Earth's Radiant Energy System (CERES) observations. Second, the anisotropy is corrected by applying Angular Distribution Models (ADMs), which convert directional reflectance into a hemispherical albedo. Third, the instantaneous albedos are temporally interpolated by a flexible diurnal cycle model, capable of ingesting any number of observations at any time of day, making it suitable for any orbital configuration of NOAA and MetOp satellites. Finally, the twilight conditions prevailing near sunrise and sunset are simulated with

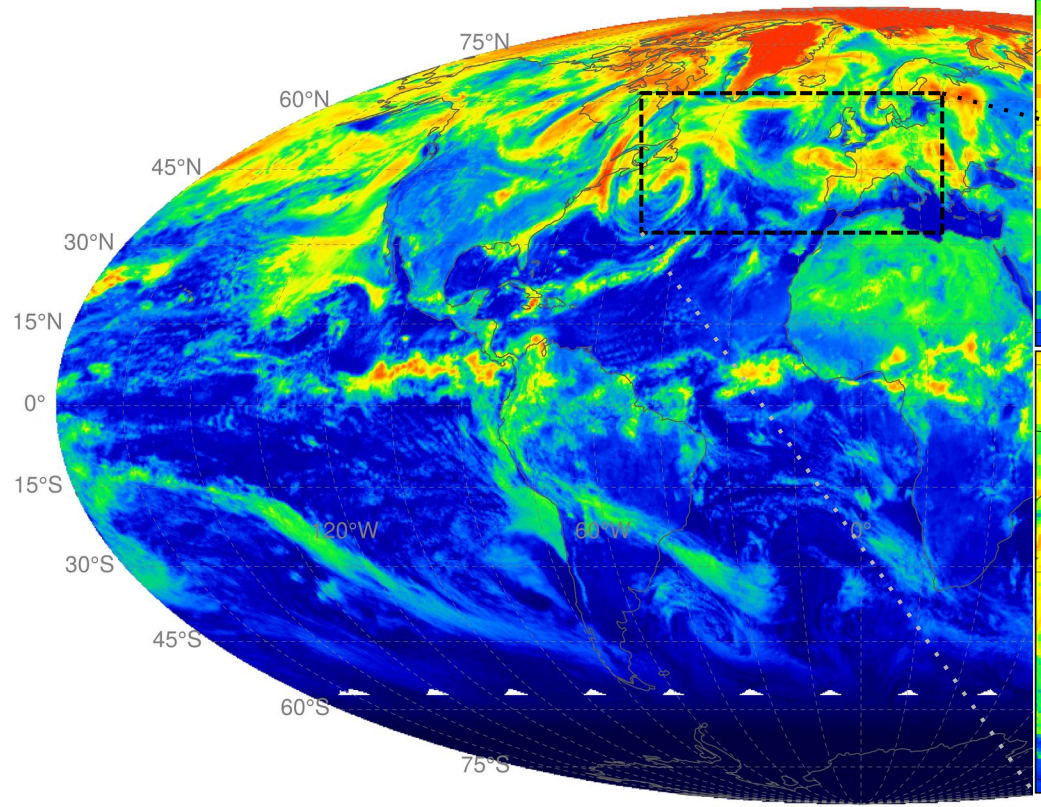
3. Results

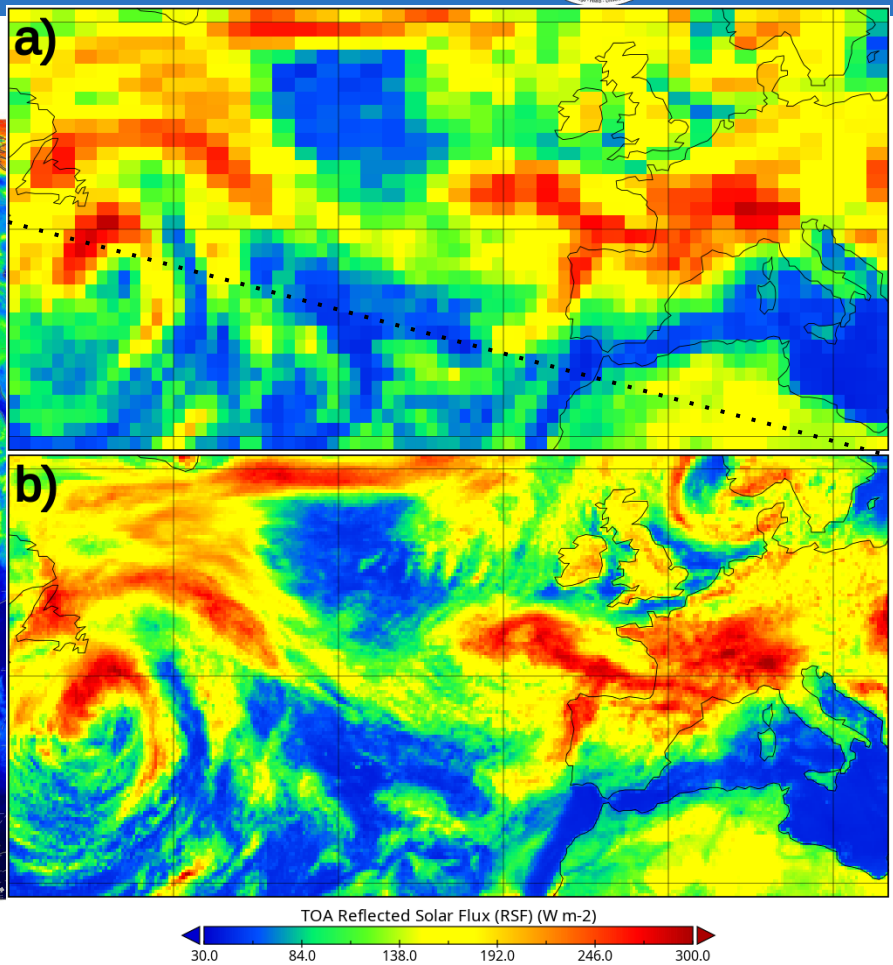
- Example: daily mean RSF (15/6/2008)



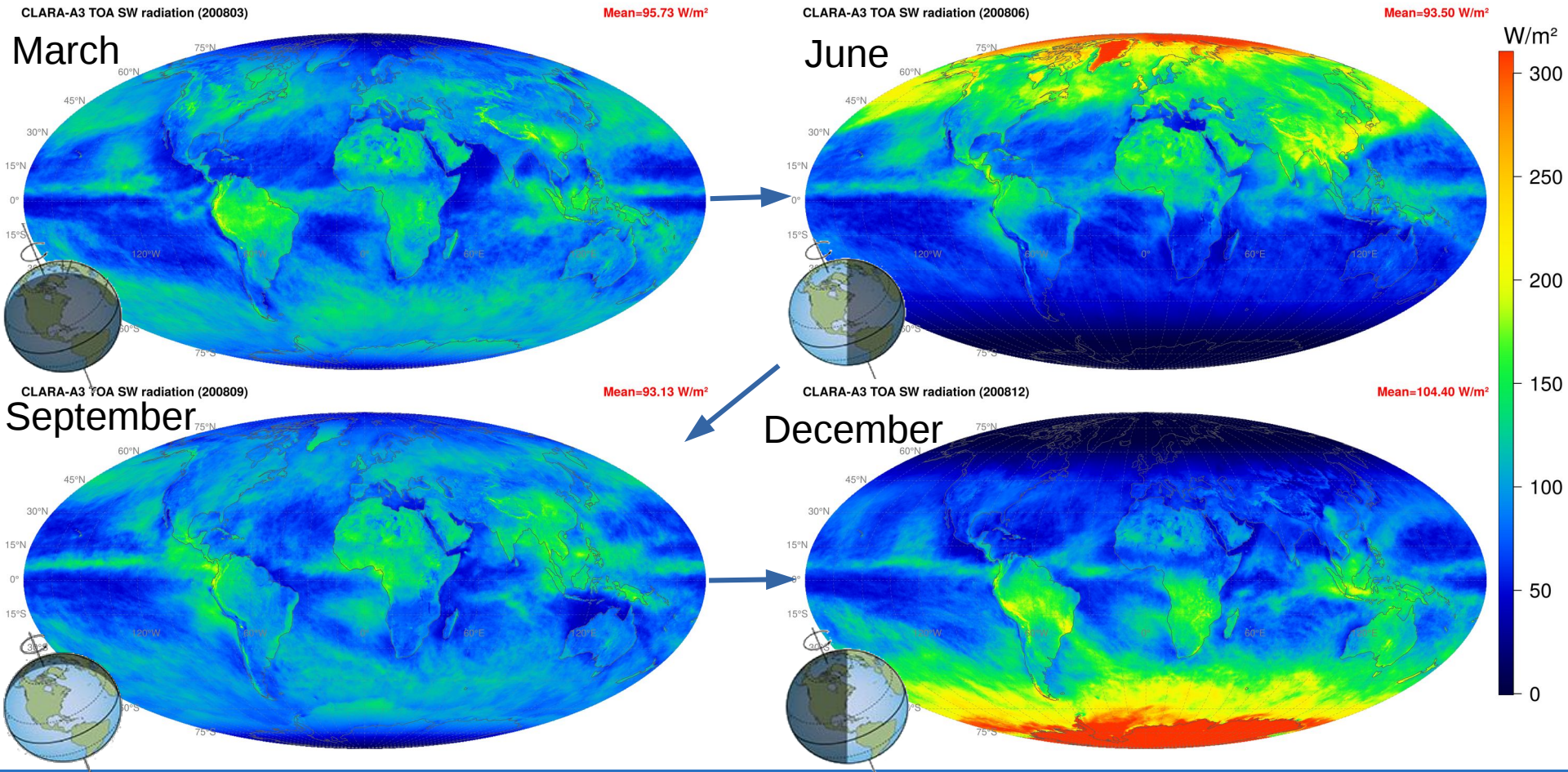
3. Results

- Example: daily mean RSF (15/6/2008)

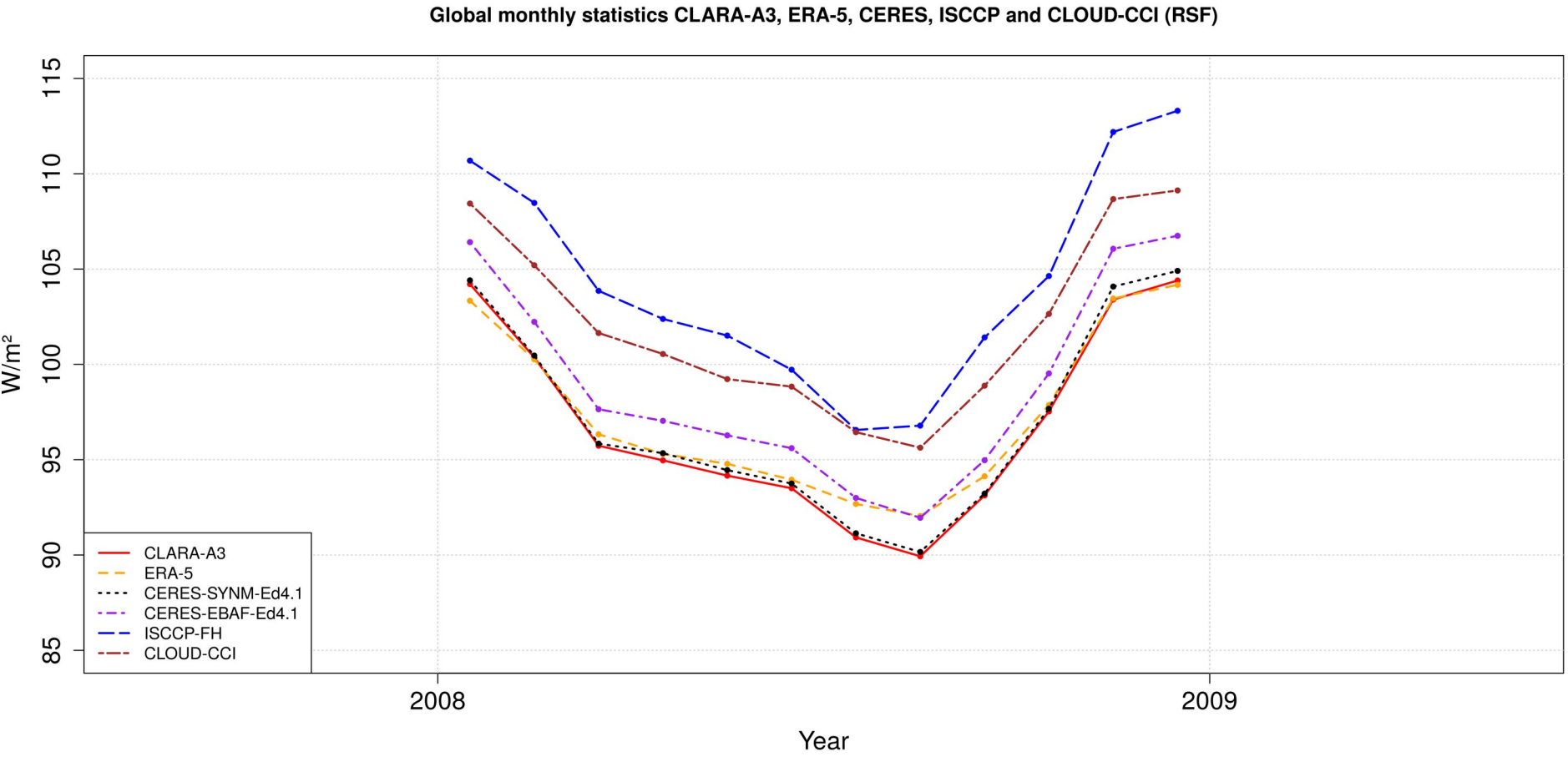




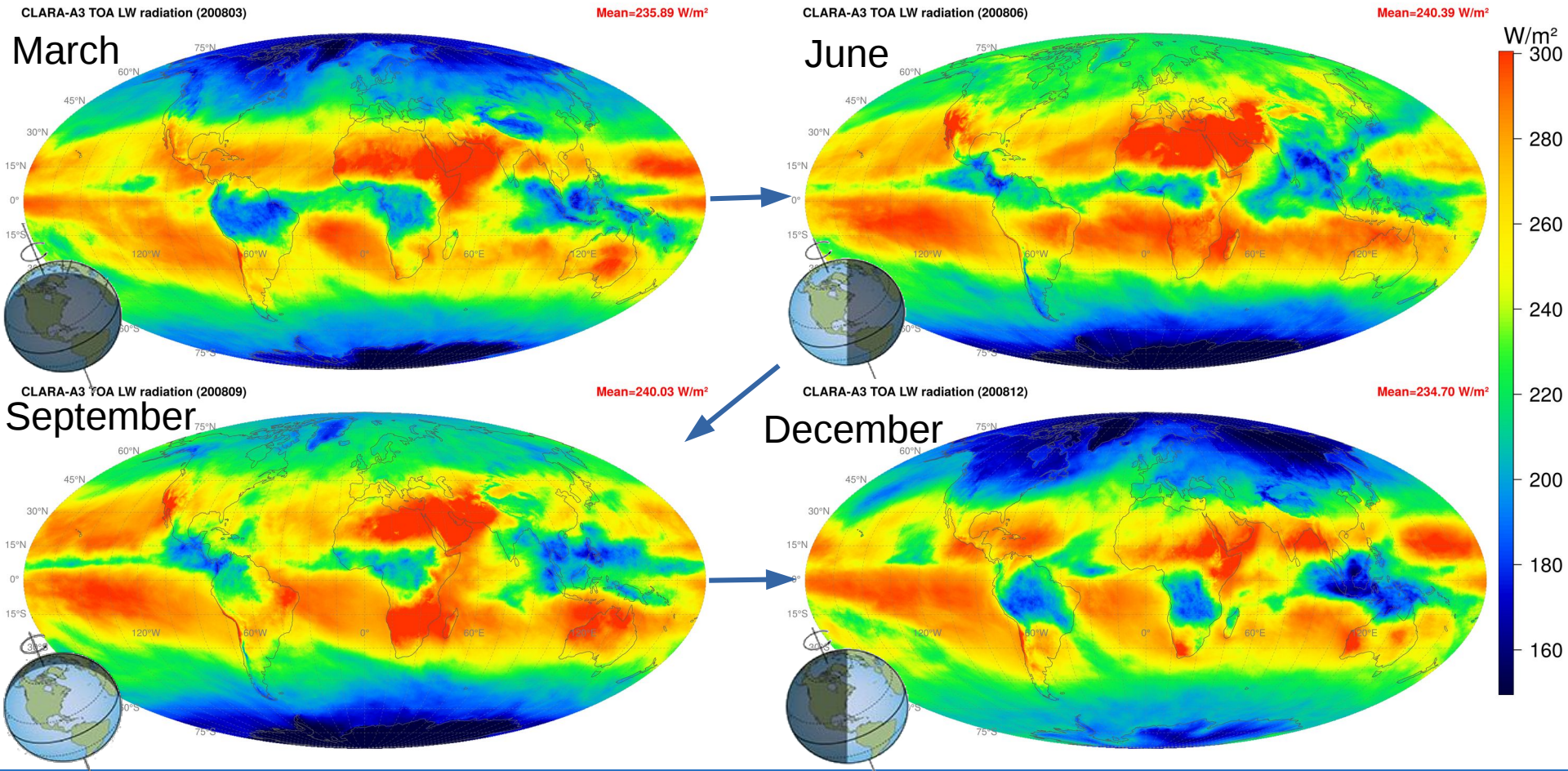
3. Results


CLARA-A3 TOA SW radiation (200803)
Mean=95.73 W/m²
March
CLARA-A3 TOA SW radiation (200806)
Mean=93.50 W/m²
June
CLARA-A3 TOA SW radiation (200809)
Mean=93.13 W/m²
September
CLARA-A3 TOA SW radiation (200812)
Mean=104.40 W/m²
December
W/m²
300
250
200
150
100
50
0

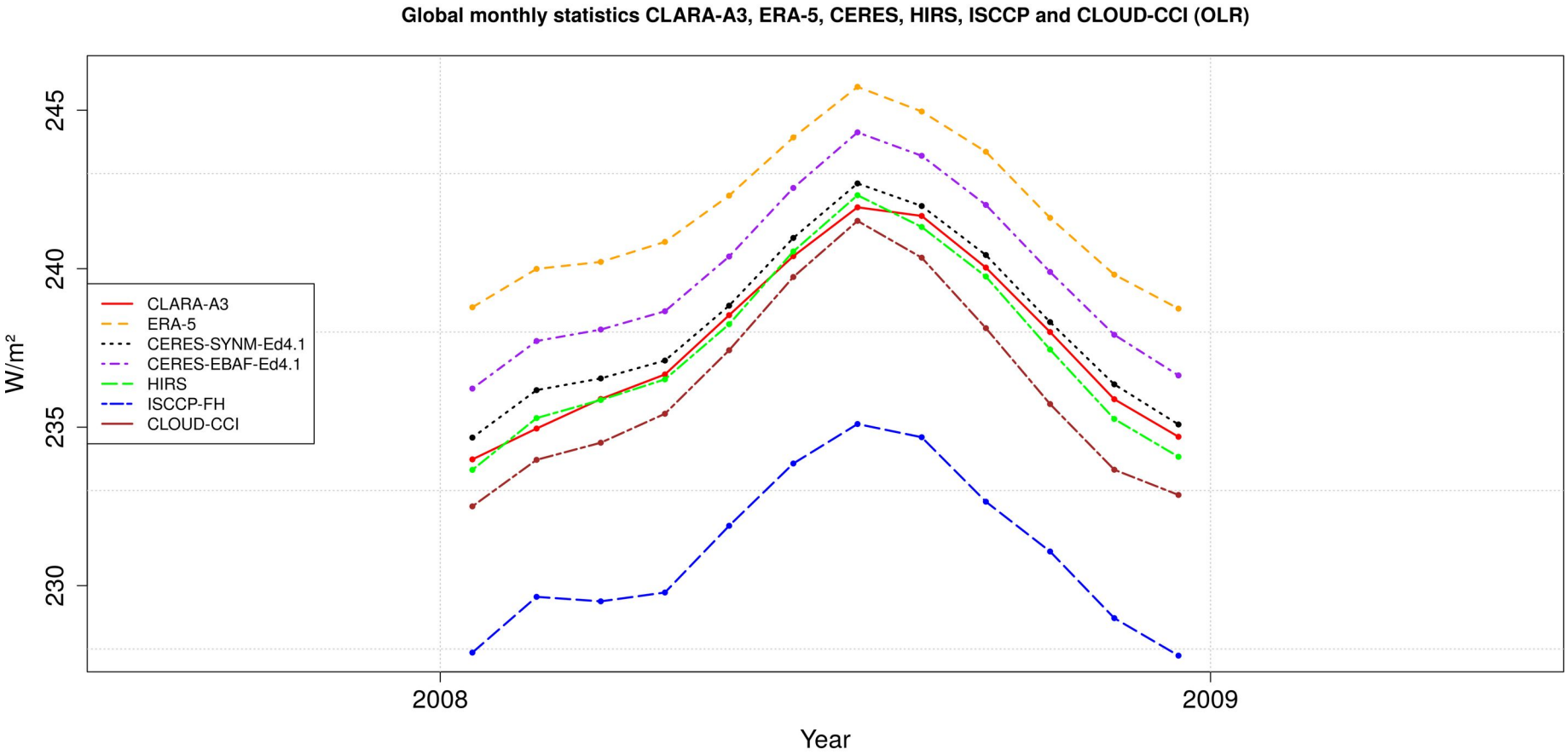
3. Results


Global monthly statistics CLARA-A3, ERA-5, CERES, ISCCP and CLOUD-CCI (RSF)
W/m²
115
110
105
100
95
90
85
2008
2009
Year
CLARA-A3
ERA-5
CERES-SYNM-Ed4.1
CERES-EBAF-Ed4.1
ISCCP-FH
CLOUD-CCI

3. Results


CLARA-A3 TOA LW radiation (200803)
Mean=235.89 W/m²
March
CLARA-A3 TOA LW radiation (200806)
Mean=240.39 W/m²
June
CLARA-A3 TOA LW radiation (200809)
Mean=240.03 W/m²
September
CLARA-A3 TOA LW radiation (200812)
Mean=234.70 W/m²
December
W/m²
300
280
260
240
220
200
180
160

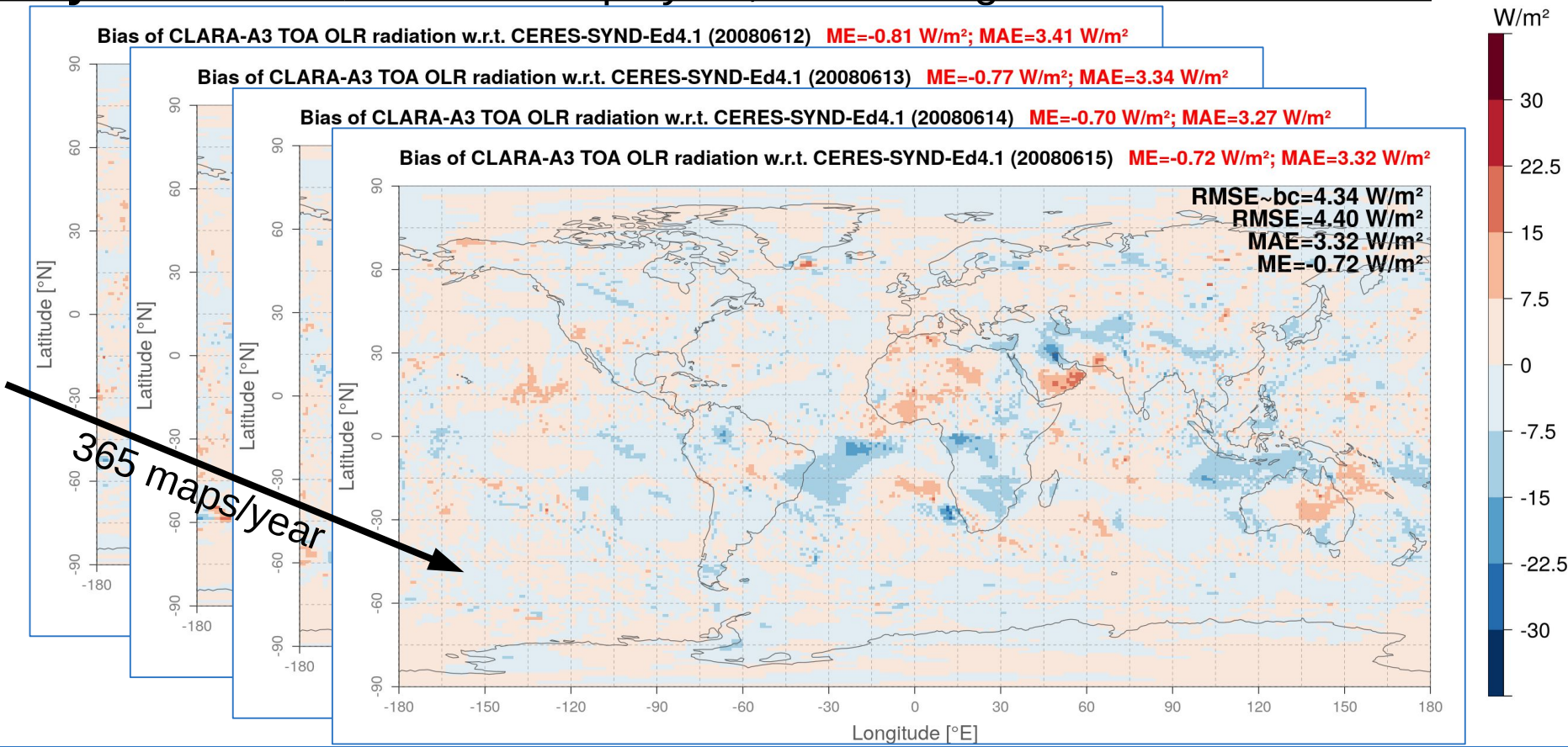
3. Results


Global monthly statistics CLARA-A3, ERA-5, CERES, HIRS, ISCCP and CLOUD-CCI (OLR)
CLARA-A3
ERA-5
CERES-SYNM-Ed4.1
CERES-EBAF-Ed4.1
HIRS
ISCCP-FH
CLOUD-CCI
W/m²
245
240
235
230
2008
2009
Year

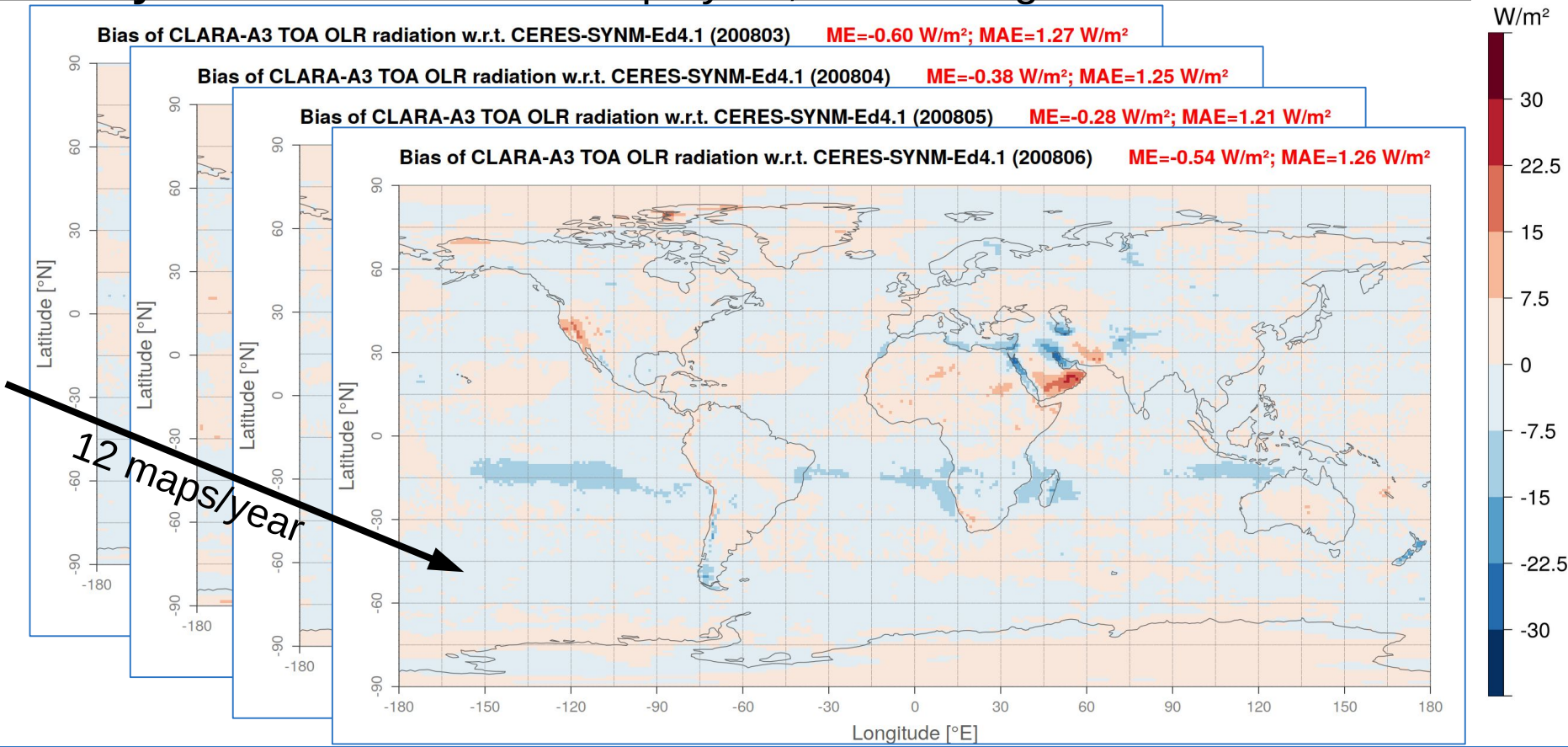
4. Validation

- ***Longwave: Outgoing Longwave Radiation :***
  - **Bias:**
    - Daily mean OLR
    - Monthly mean OLR
  - **RMSE (bias corrected):**
    - Daily mean OLR
    - Monthly mean OLR
- ***Shortwave: Reflected Solar Flux :***
  - **Bias:**
    - Daily mean RSF
    - Monthly mean RSF
  - **RMSE (bias corrected):**
    - Daily mean RSF
    - Monthly mean RSF
  - **MAB (daily and hourly)**

- **Daily mean OLR:** 365 bias maps/year, each with global bias and RMSE:

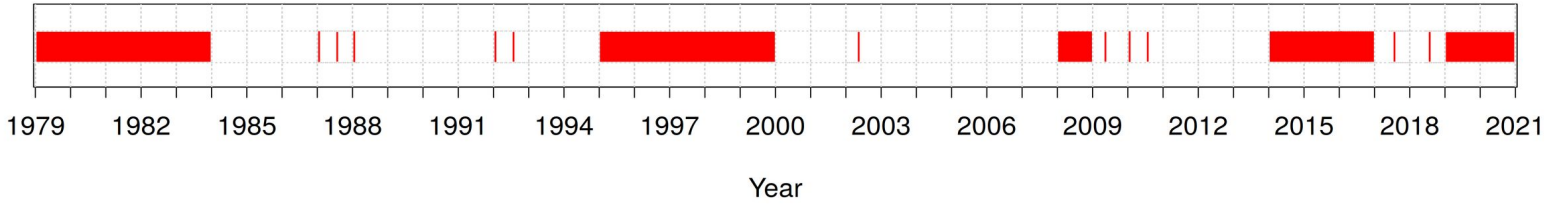


- **Monthly mean OLR:** 12 bias maps/year, each with global bias and RMSE:



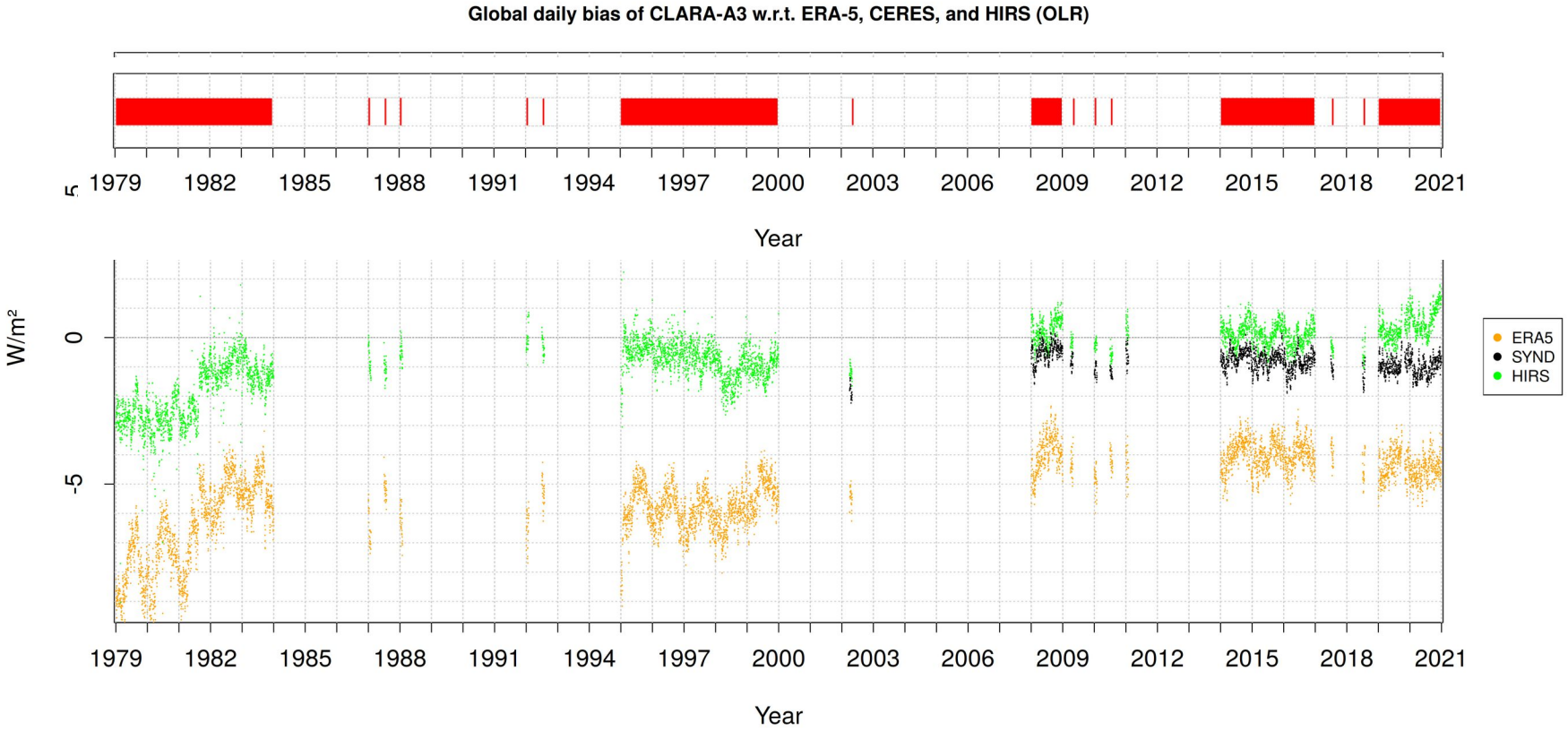
4. Validation

- Actual temporal coverage of CLARA-A3 (currently being generated…):



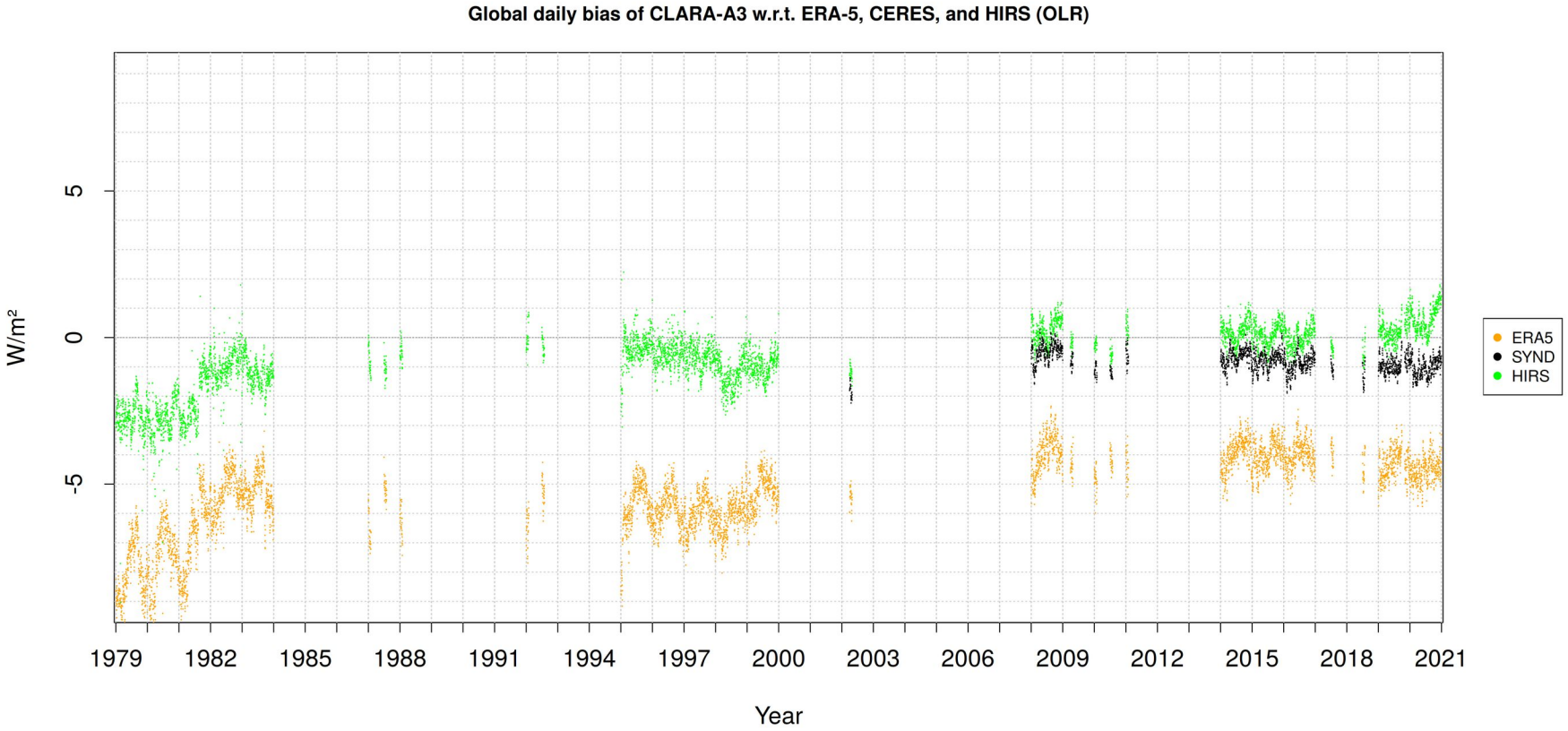
4. Validation

- **Global mean bias** of Daily Mean OLR:



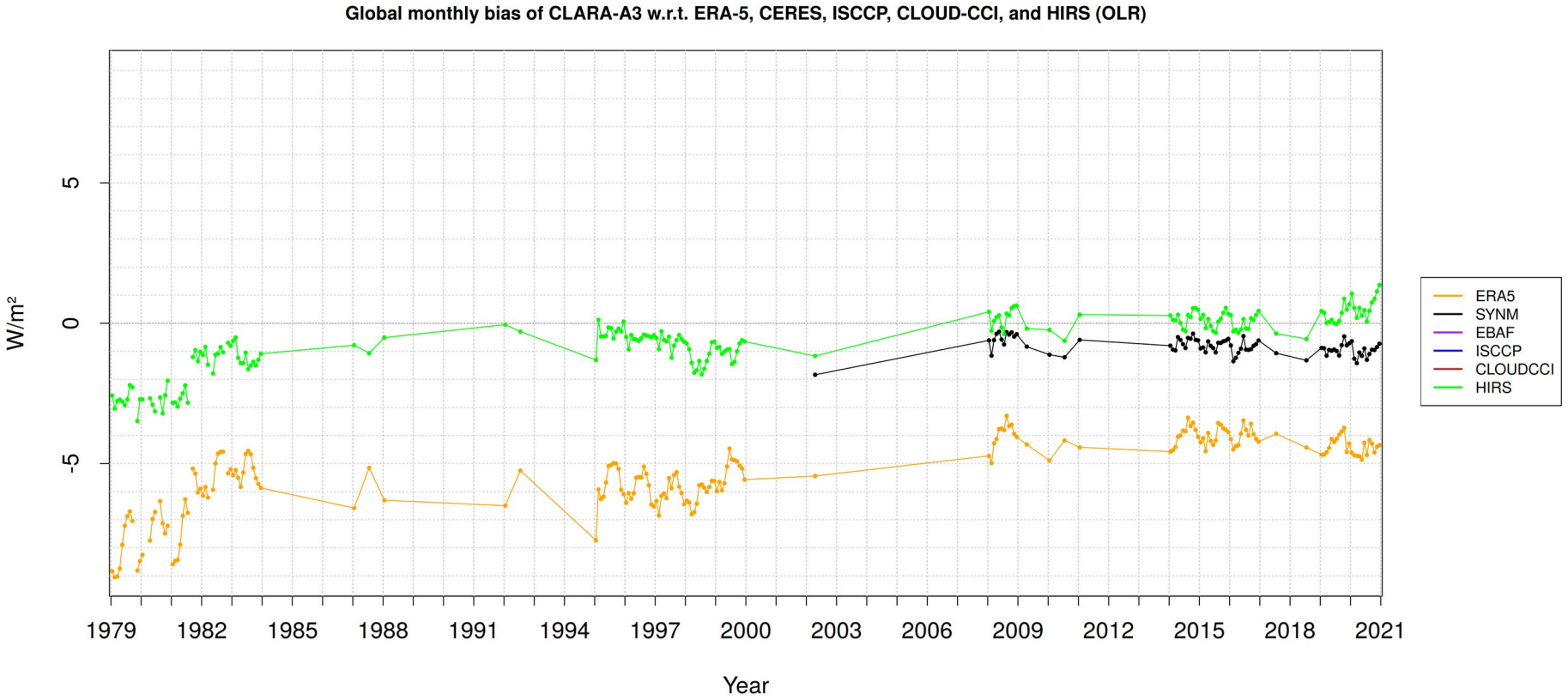
4. Validation

- **Global mean bias** of Daily Mean OLR:



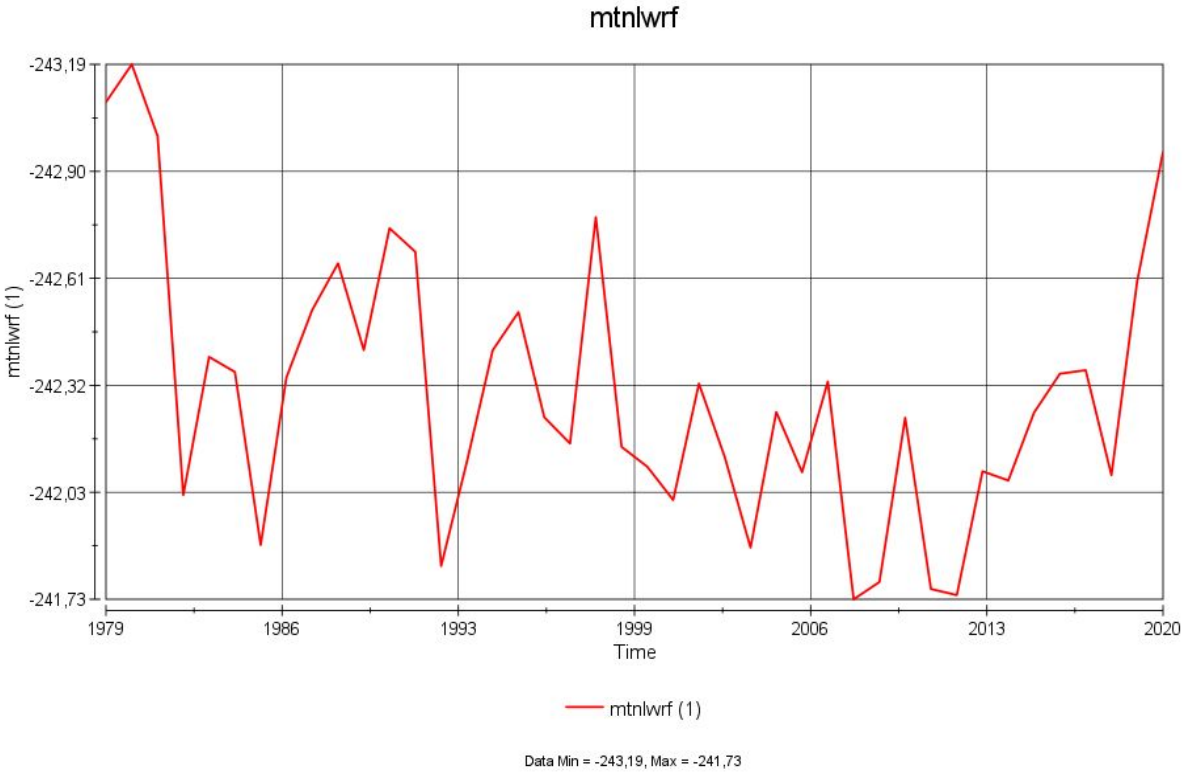
4. Validation

- **Global mean bias** of Monthly Mean OLR:



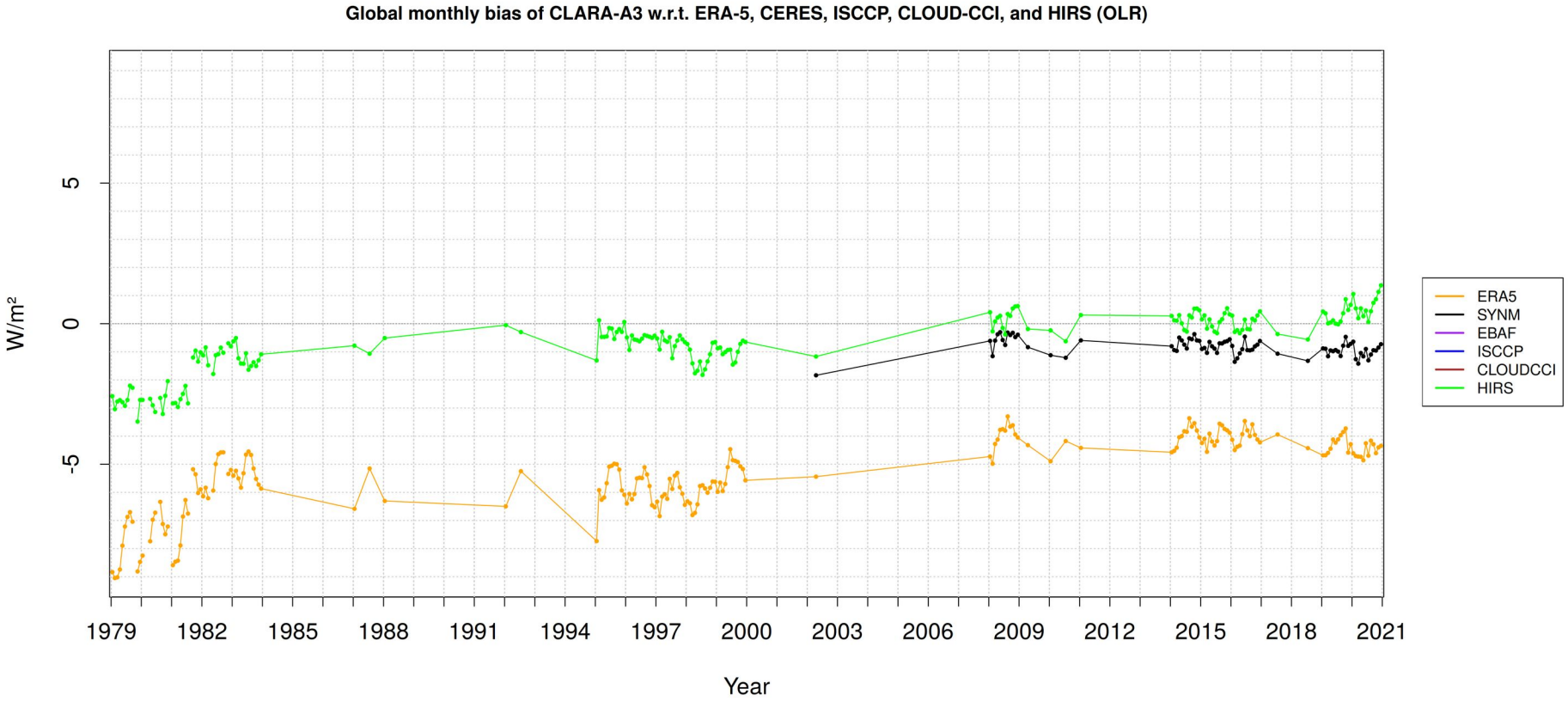
4. Validation

- **ERA5** annual mean OLR:

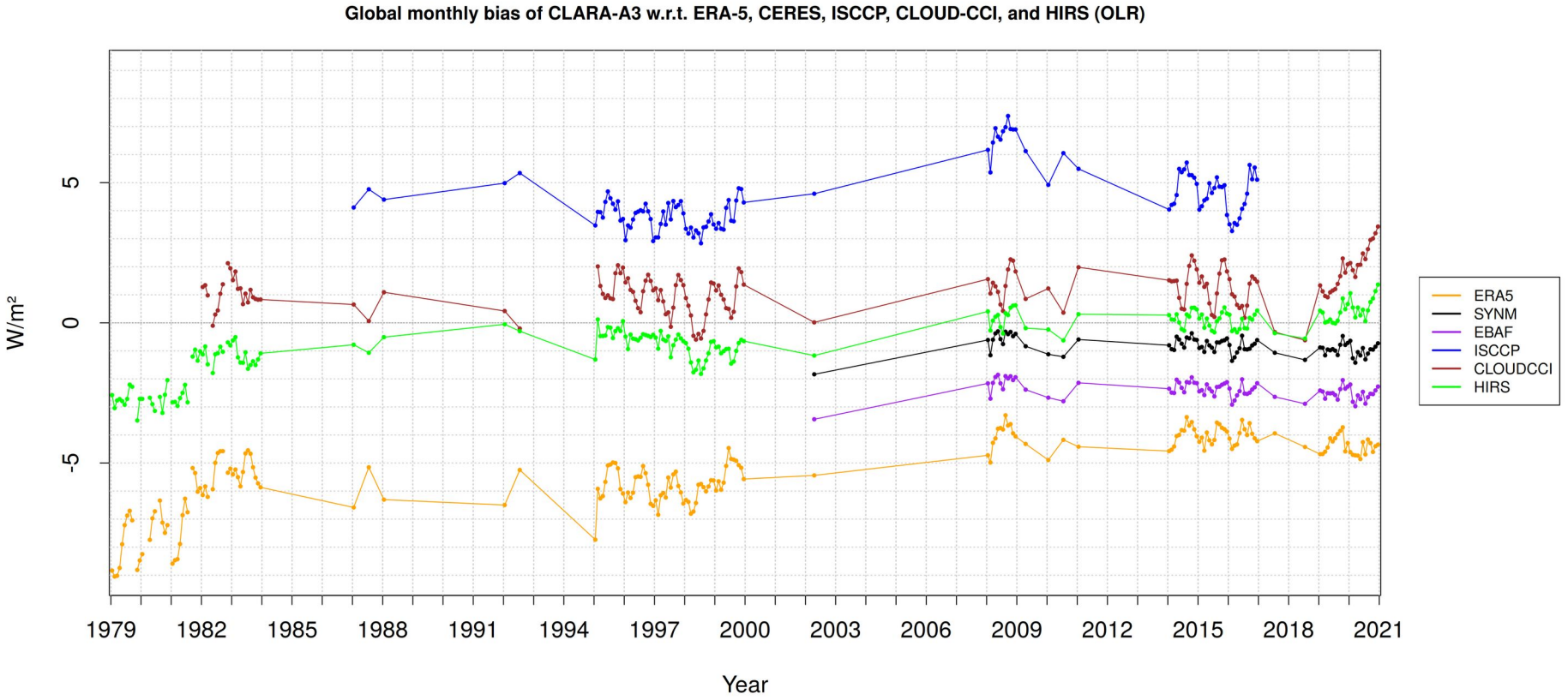


4. Validation

- **Global mean bias** of Monthly Mean OLR:

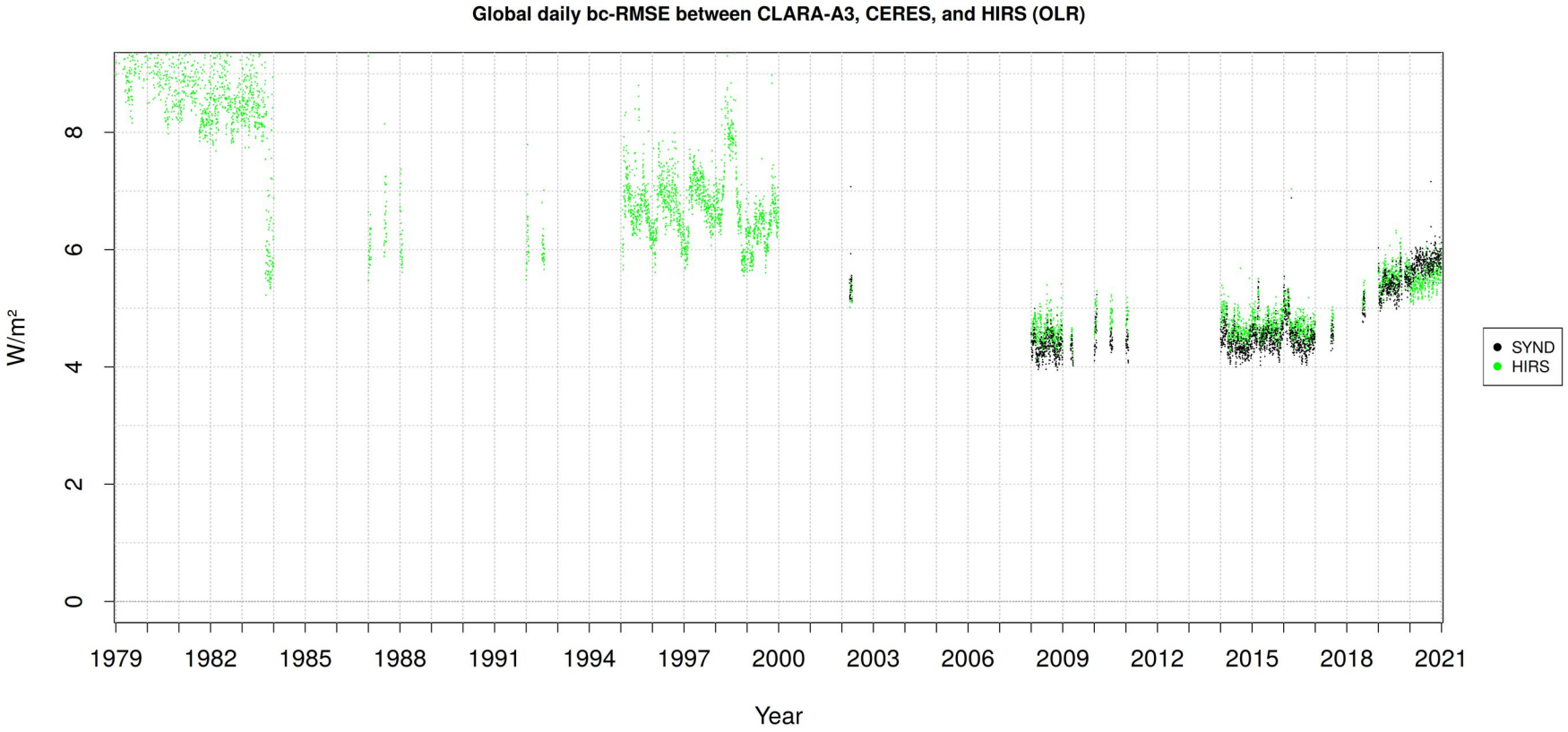


- **Global mean bias** of Monthly Mean OLR:



4. Validation

- **Global RMSE (bias-corrected)** of Daily Mean OLR:



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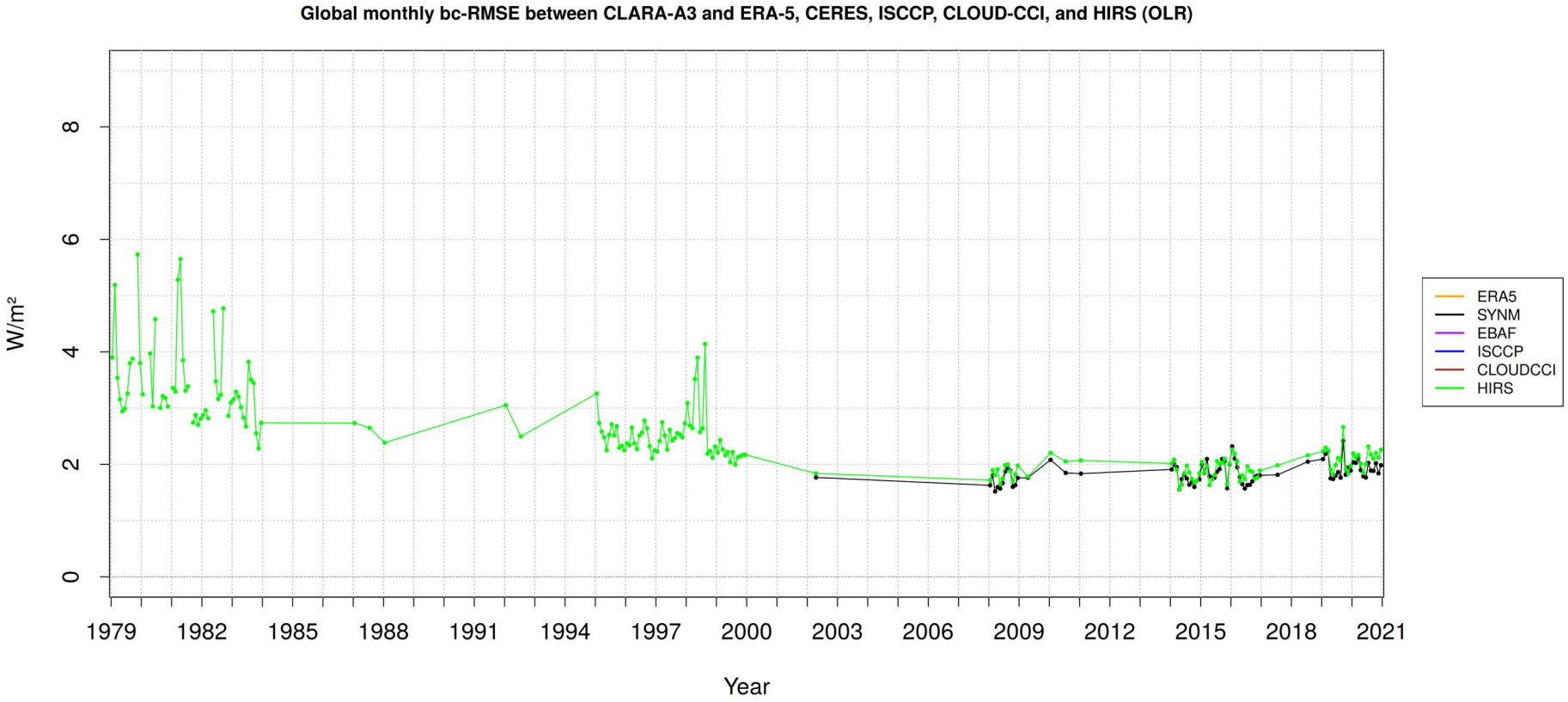
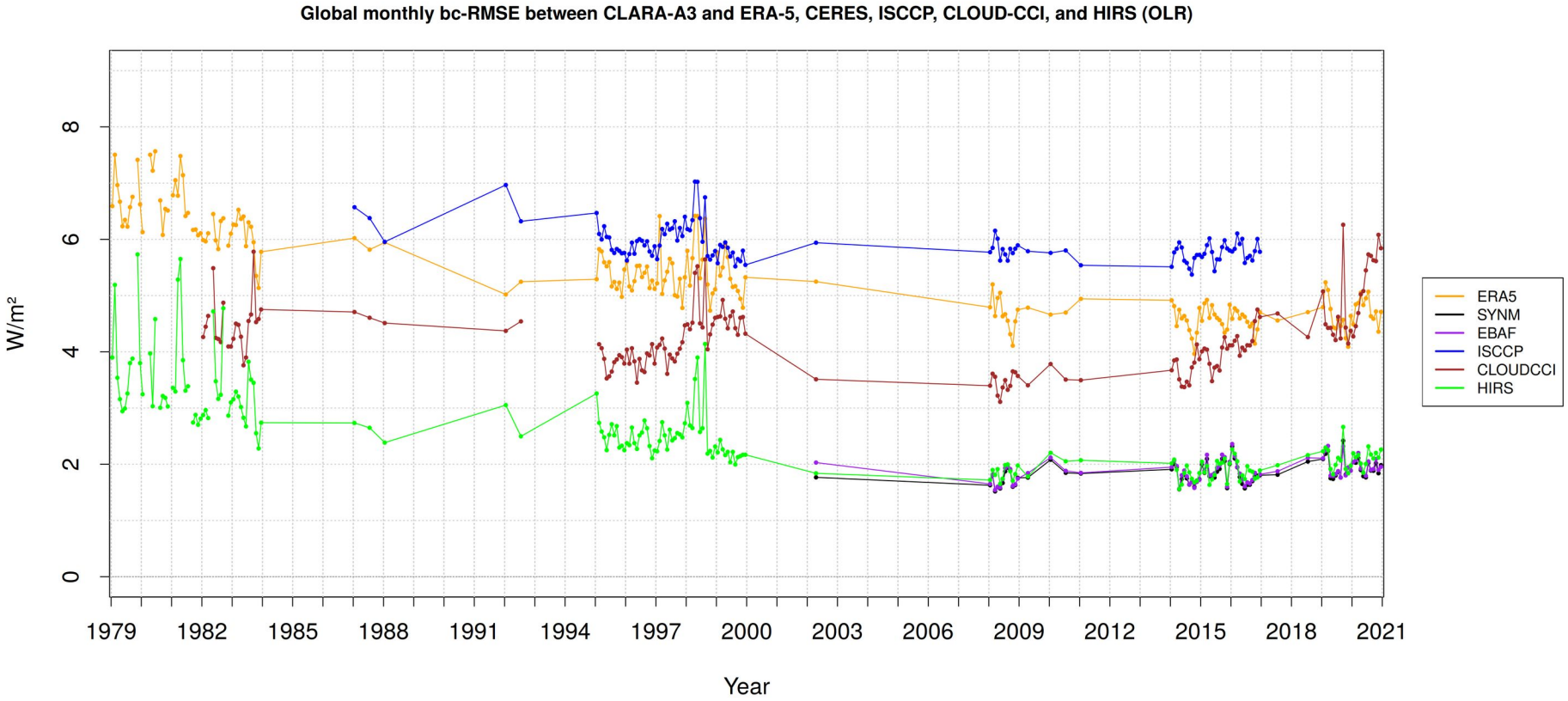


4. Validation

- **Global RMSE (bias-corrected)** of Monthly Mean OLR:

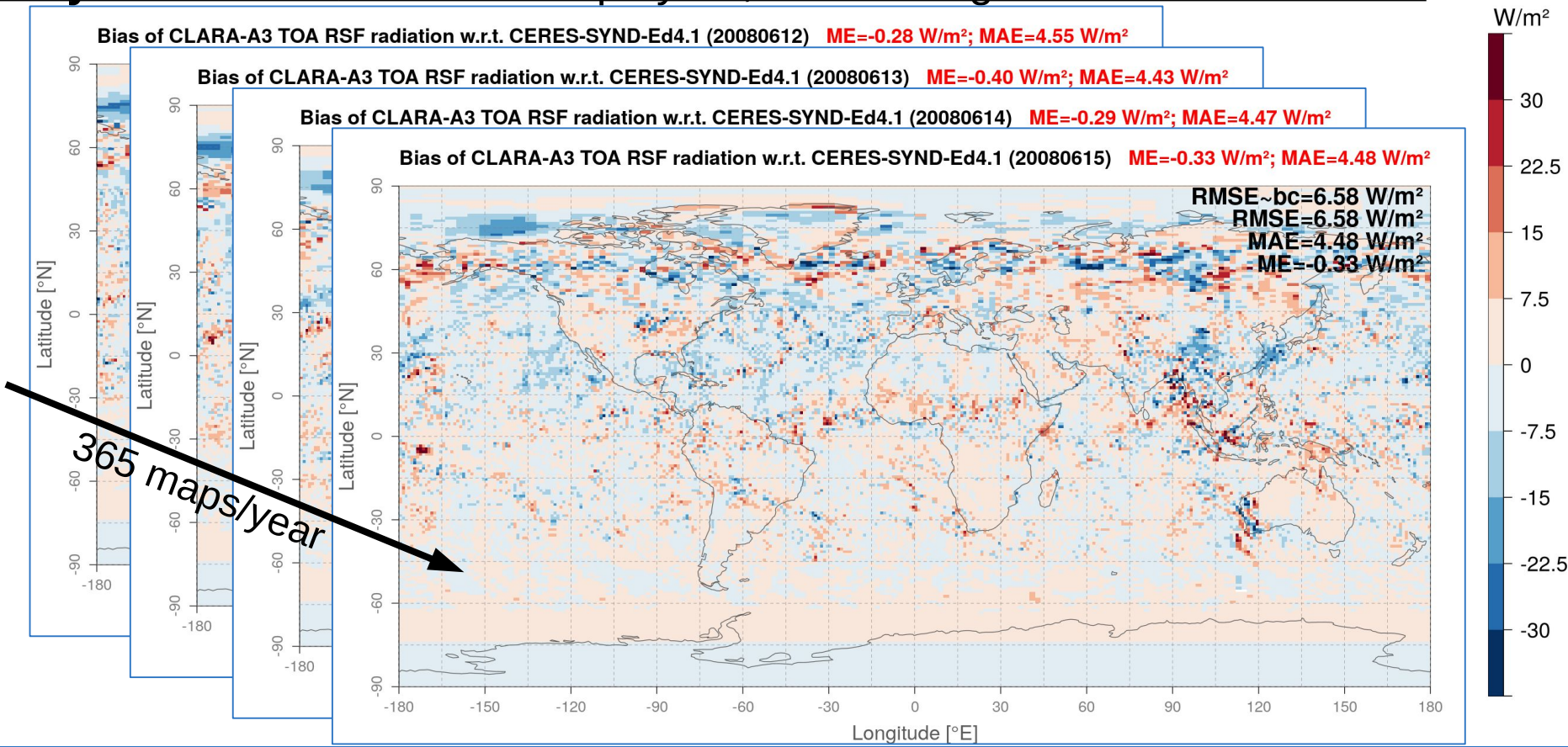


4. Validation

- ***Longwave: Outgoing Longwave Radiation :***
  - **Bias:**
    - Daily mean OLR
    - Monthly mean OLR
  - **RMSE (bias corrected):**
    - Daily mean OLR
    - Monthly mean OLR
- ***Shortwave: Reflected Solar Flux :***
  - **Bias:**
    - Daily mean RSF
    - Monthly mean RSF
  - **RMSE (bias corrected):**
    - Daily mean RSF
    - Monthly mean RSF
  - **MAB (daily and hourly)**

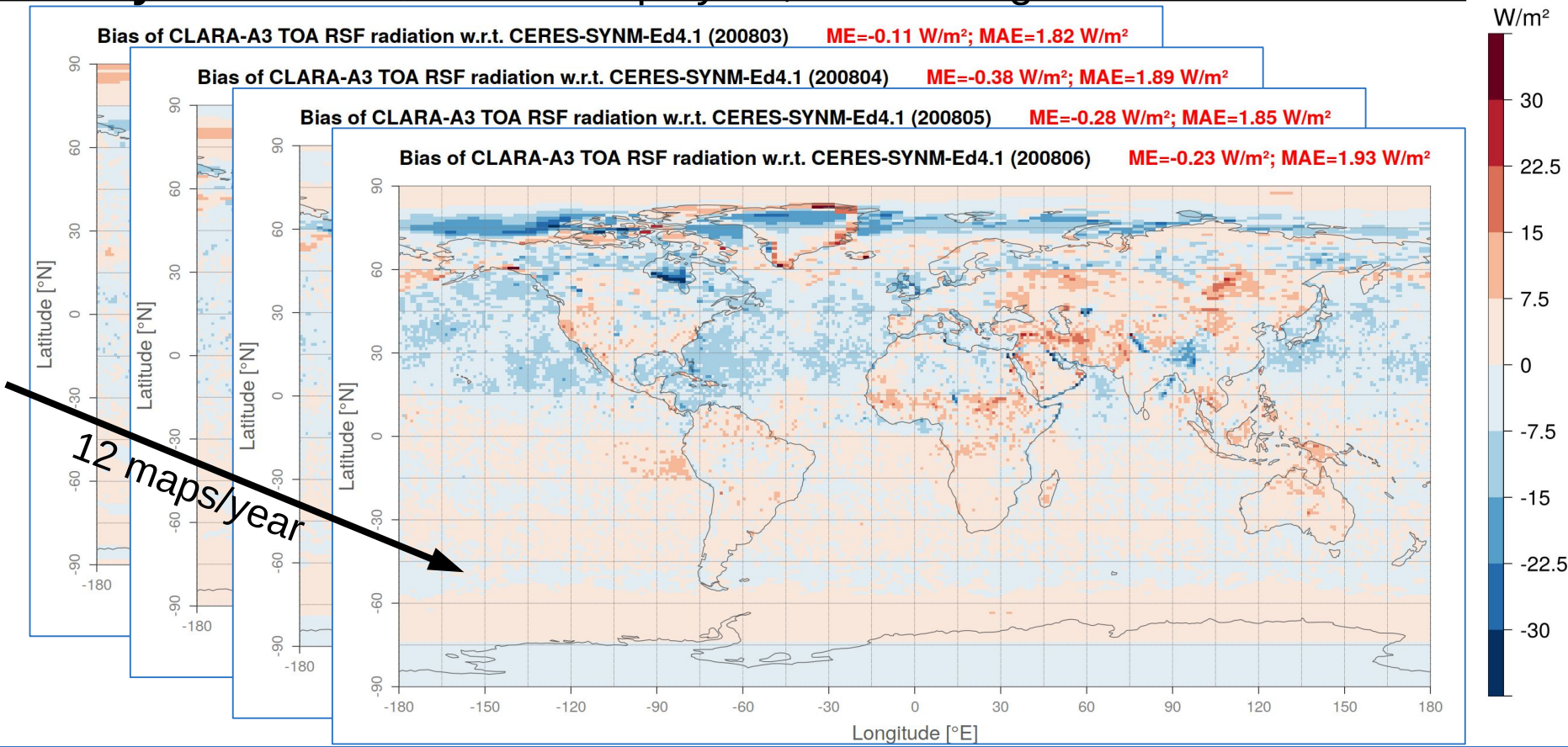
4. Validation

- **Daily mean RSF:** 365 bias maps/year, each with global bias and RMSE:



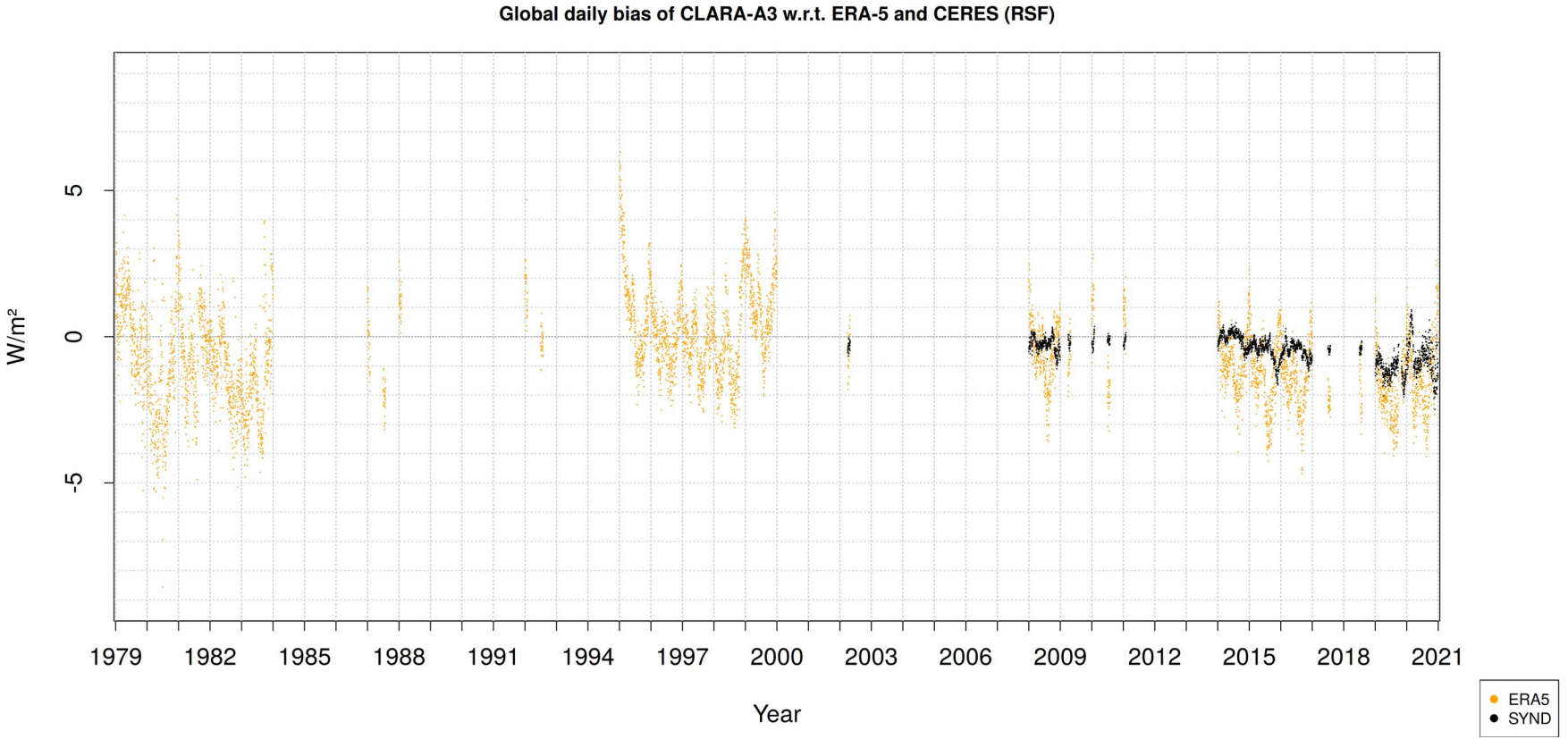
4. Validation

- **Monthly mean RSF:** 12 bias maps/year, each with global bias and RMSE:



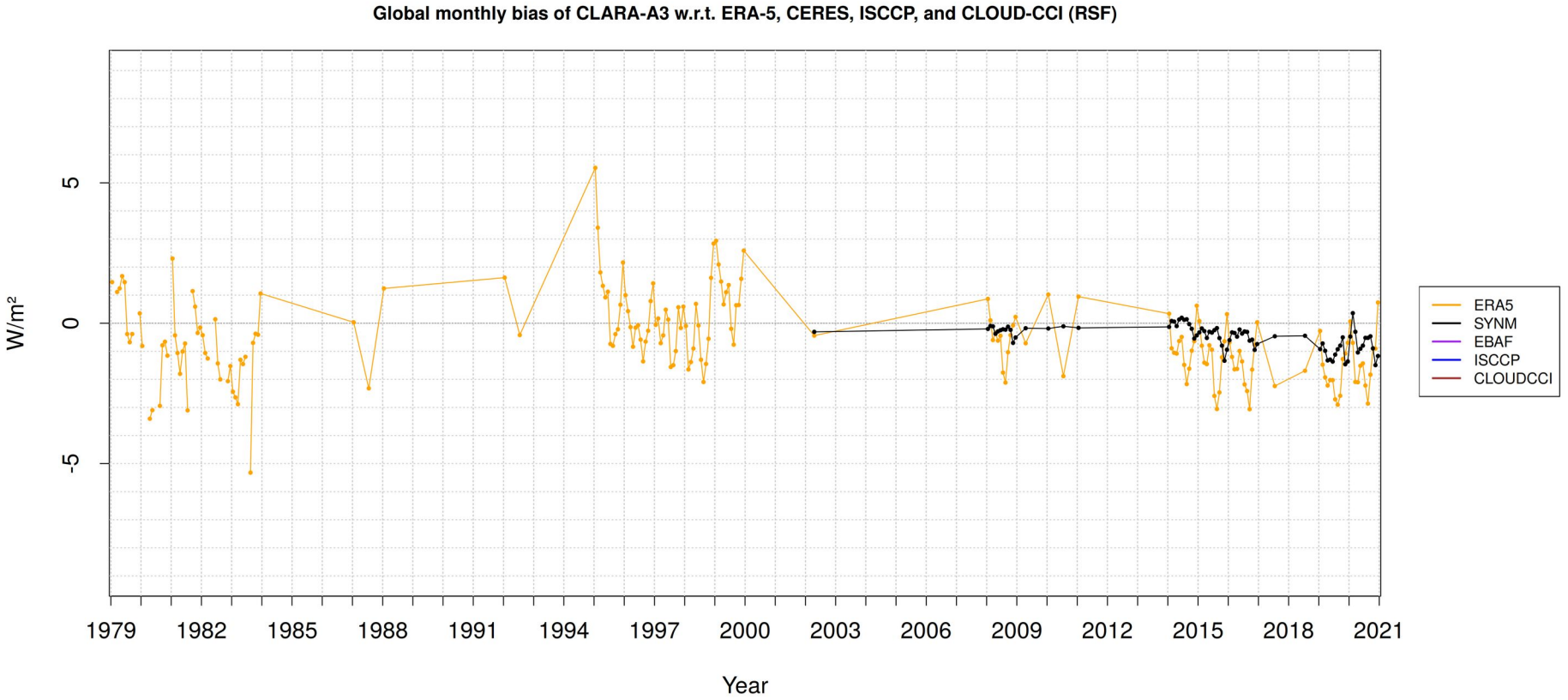
4. Validation

- **Global mean bias** of Daily Mean RSF:



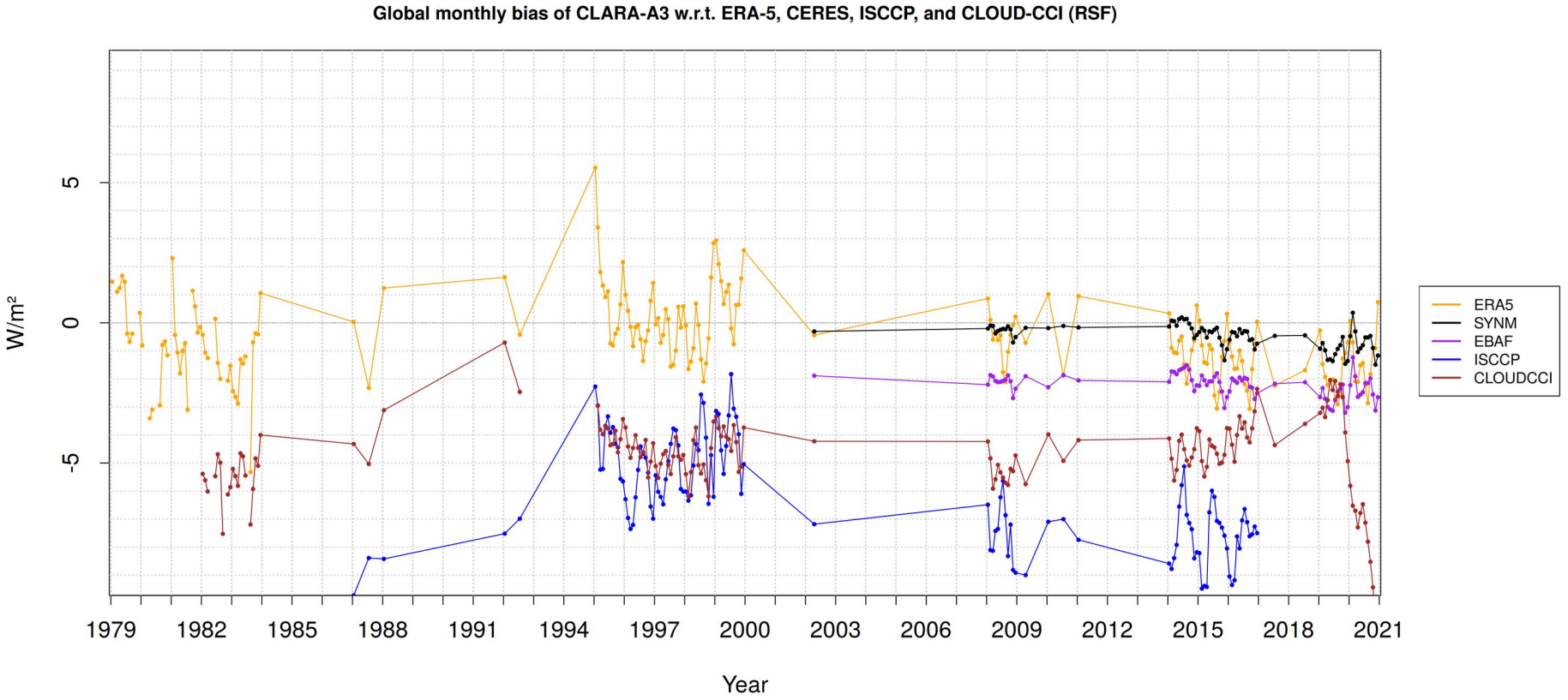
4. Validation

- **Global mean bias** of Monthly Mean RSF:



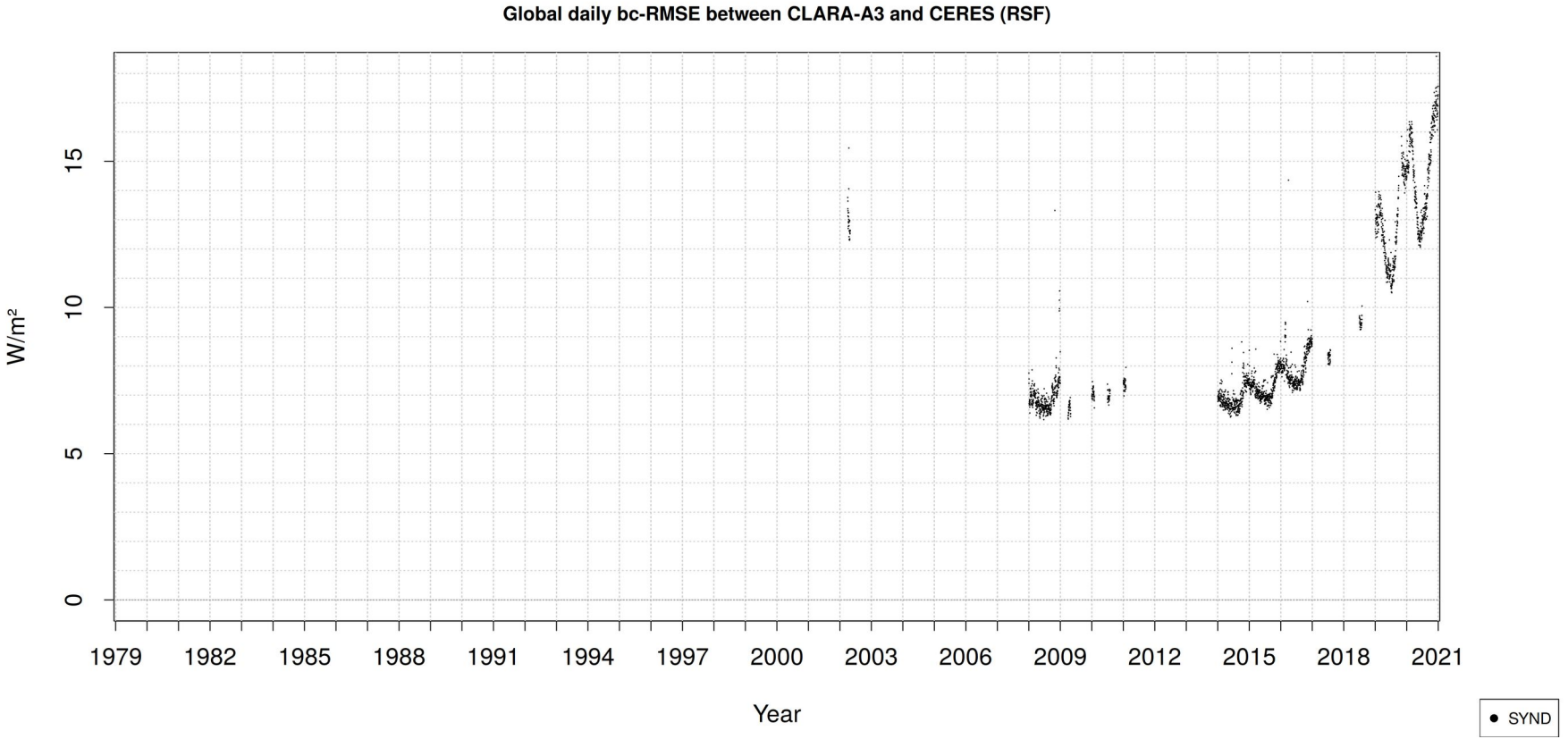
4. Validation

- **Global mean bias** of Monthly Mean RSF:



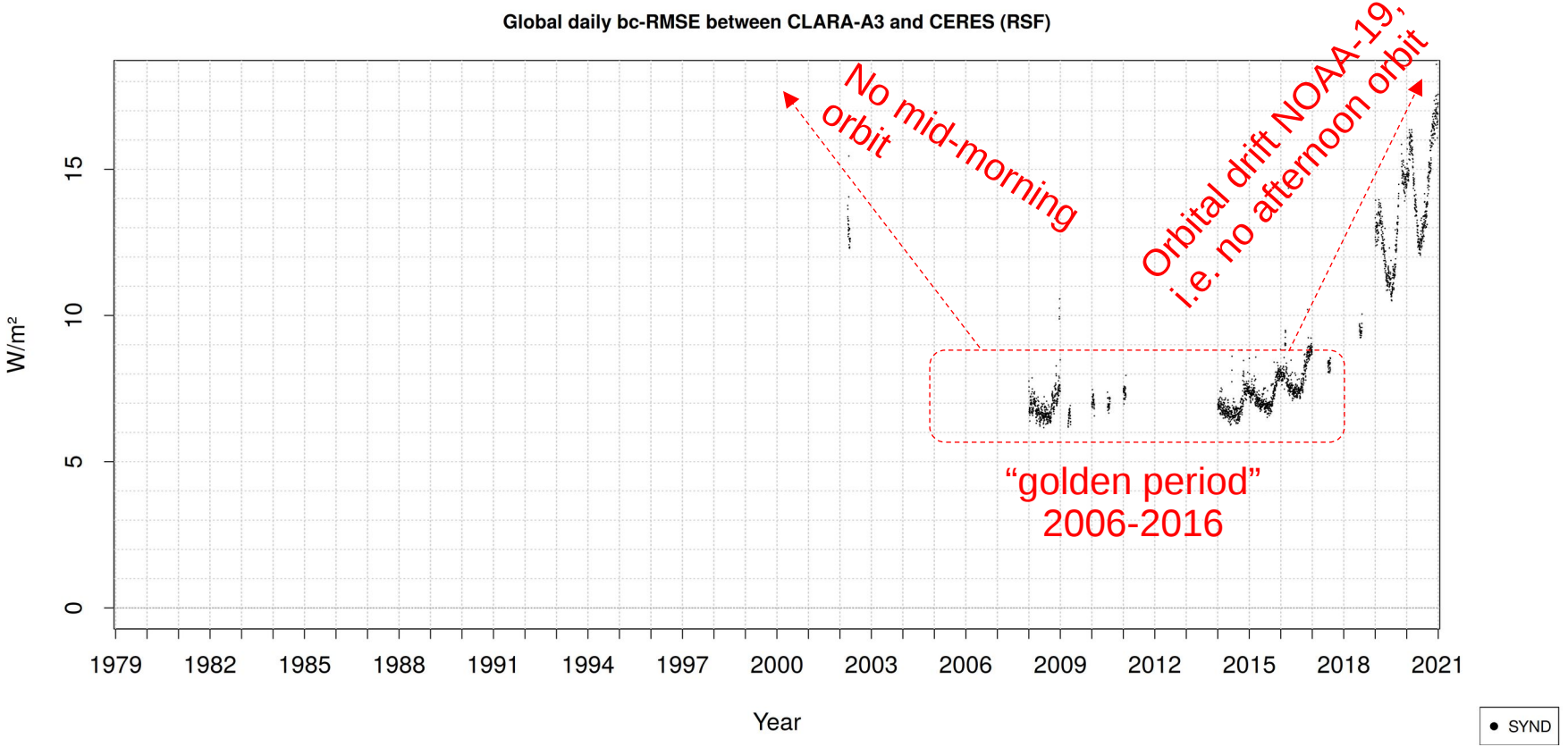
4. Validation

- **Global RMSE (bias-corrected)** of Daily Mean RSF:



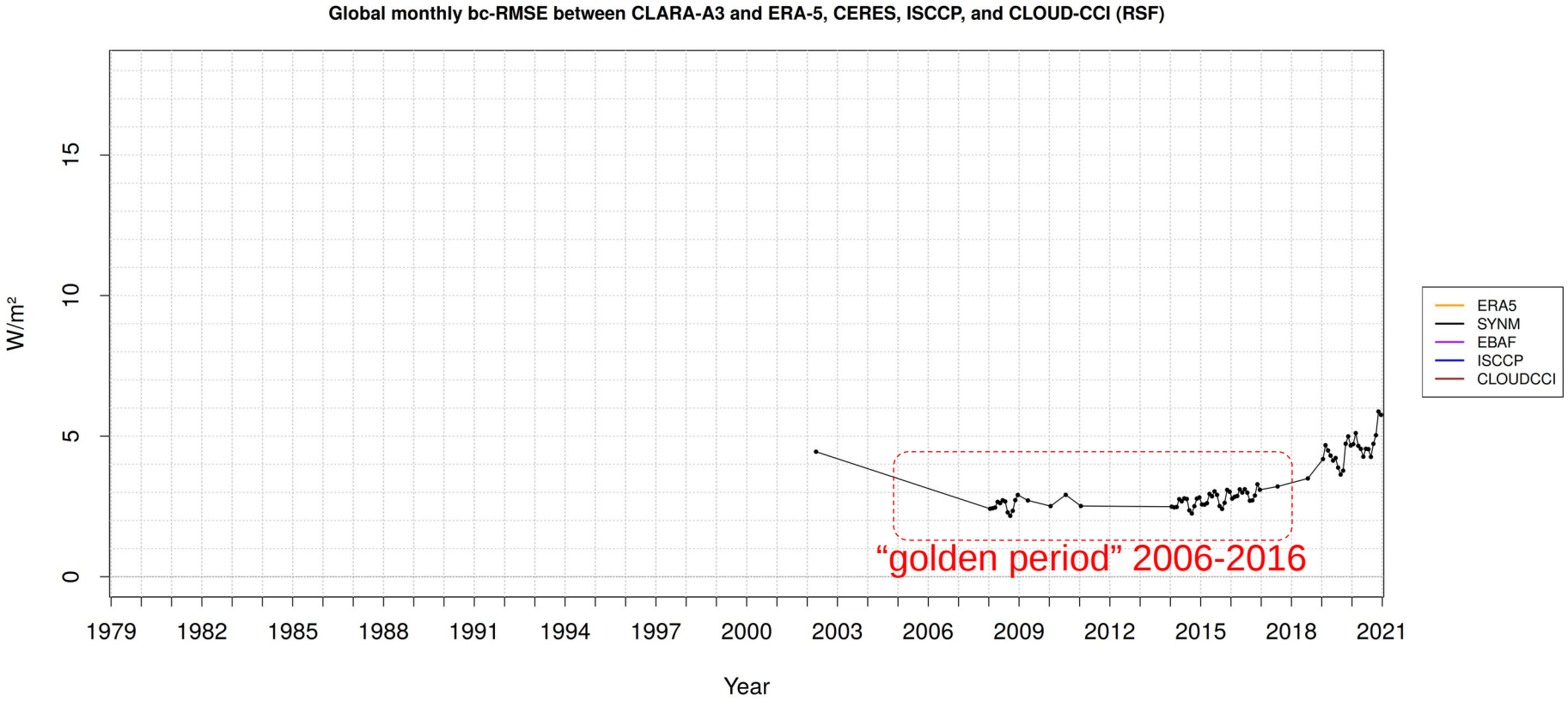
4. Validation

- **Global RMSE (bias-corrected)** of Daily Mean RSF:



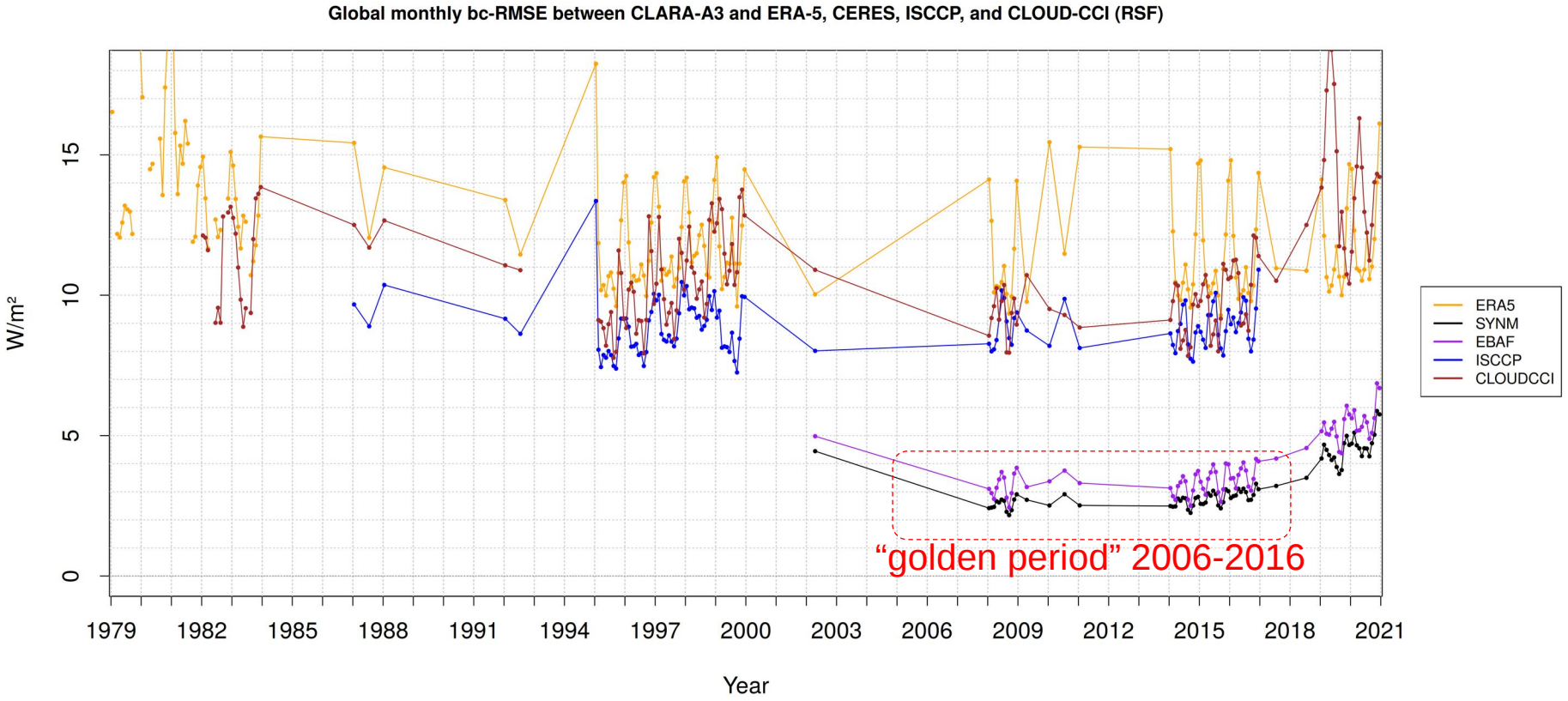
4. Validation

- **Global RMSE (bias-corrected)** of Monthly Mean RSF:



4. Validation

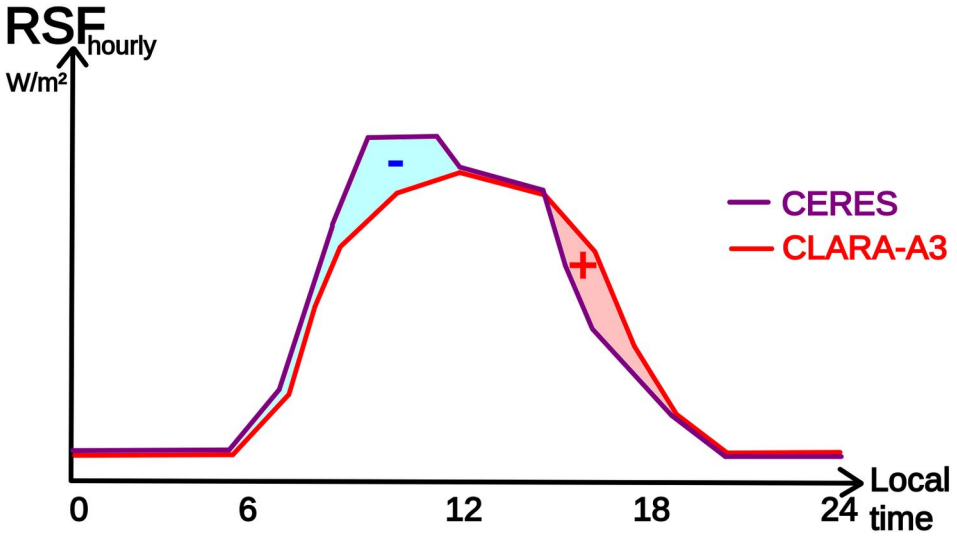
- **Global RMSE (bias-corrected)** of Monthly Mean RSF:



4. Validation

- Until now: use of daily and monthly mean RSF. But what about intra-day compensating errors?

Do they exist? If yes, do they cause or dominate the validation timeseries that is based on daily mean RSF?



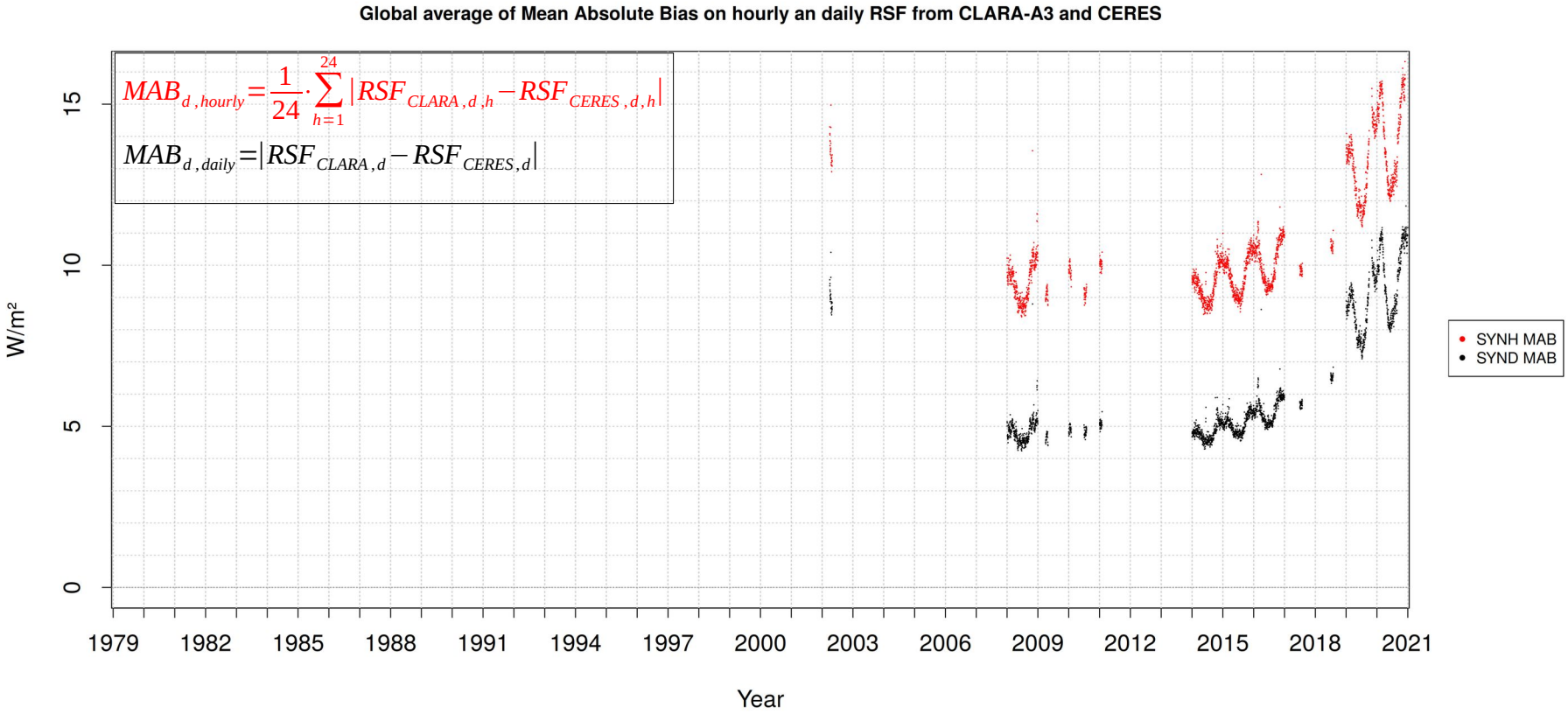
- **Mean Absolute Bias** (MAB) for day *d*, calculated from daily and hourly RSF:

$$MAB_{d,daily} = \left| RSF_{CLARA,d} - RSF_{CERES,d} \right|$$

$$MAB_{d,hourly} = \frac{1}{24} \cdot \sum_{h=1}^{24} \left| RSF_{CLARA,d,h} - RSF_{CERES,d,h} \right|$$

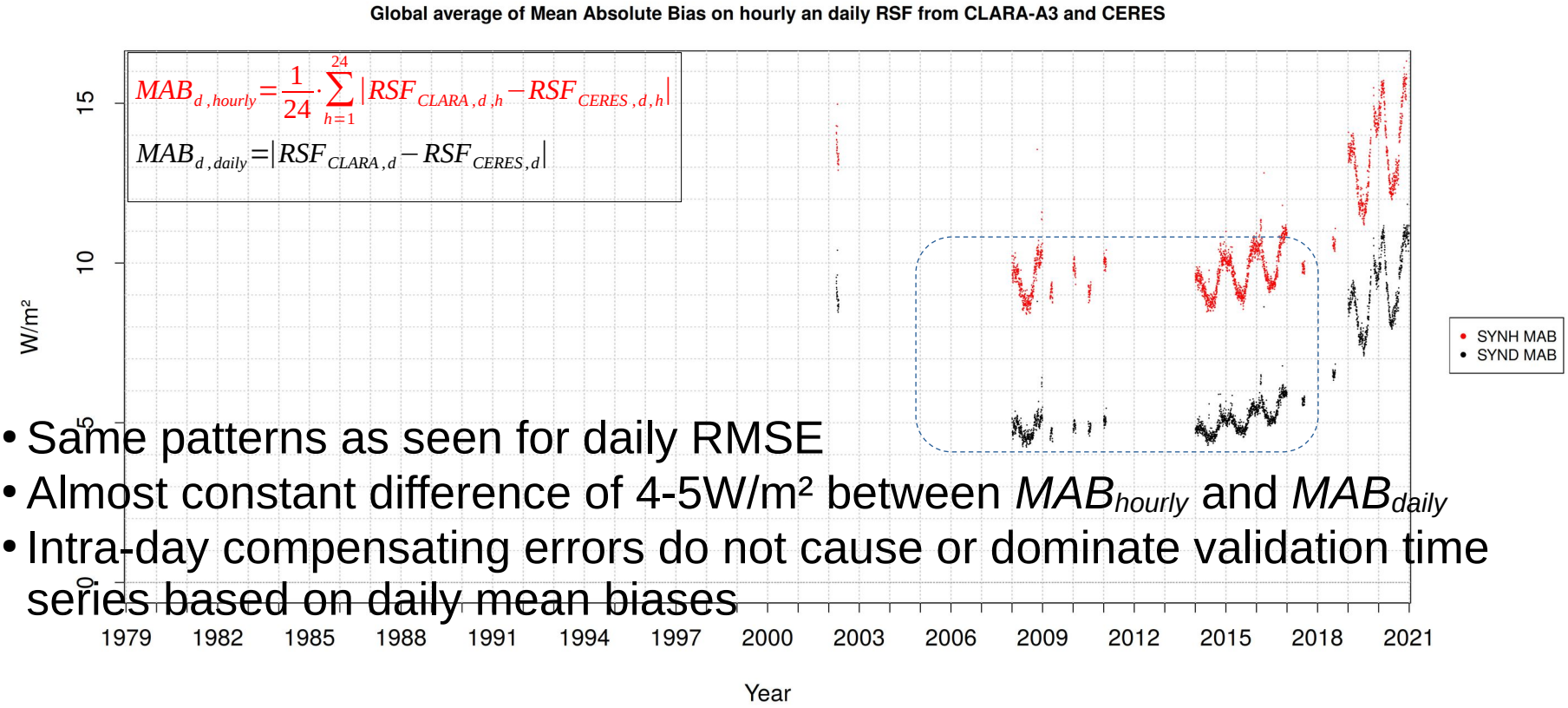
4. Validation

- Mean Absolute Bias for each day *d*, from **daily** and **hourly** RSF:



4. Validation

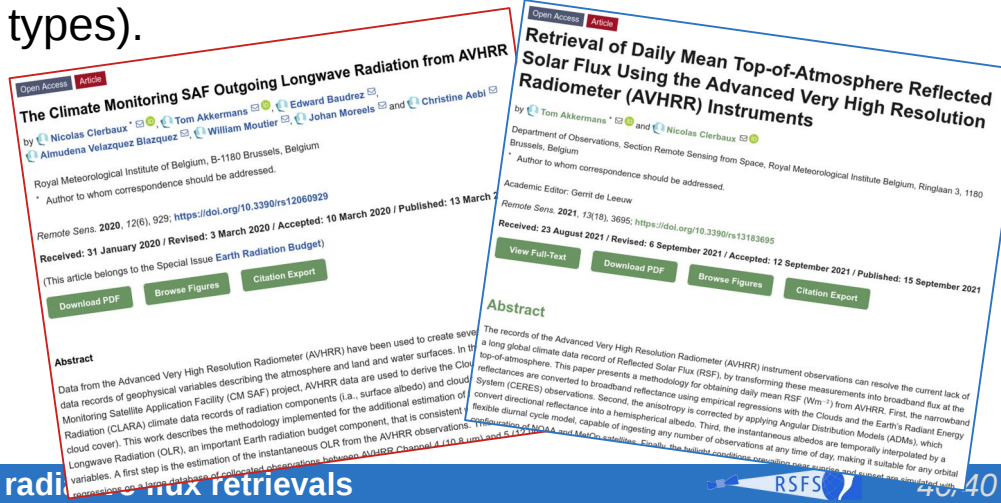
- Mean Absolute Bias for each day *d*, from **daily** and **hourly** RSF:



- Same patterns as seen for daily RMSE
- Almost constant difference of 4-5W/m² between MAB_{hourly} and MAB_{daily}
- Intra-day compensating errors do not cause or dominate validation time series based on daily mean biases

5. Future outlook

- Full data record of **CLARA-A3** is currently being generated. After validation, release is foreseen around mid-2022; an ICDR will also be developed
- Update **CLARA-A3.5** will include VIIRS instrument (S-NPP and NOAA-20) without any code changes (i.e. to be used as extension to CLARA-A3)
- Potential code updates will be done as part of **CLARA-A4** (within CMSAF), or as stand-alone data record (within RMIB), including:
  - Use of new CERES ADM's Ed4 (currently being implemented and tested at RMIB)
  - Use of new Narrowband-to-broadband regressions (based on reflectances with updated calibration coefficients, and updated scene types).



Thanks for your attention!

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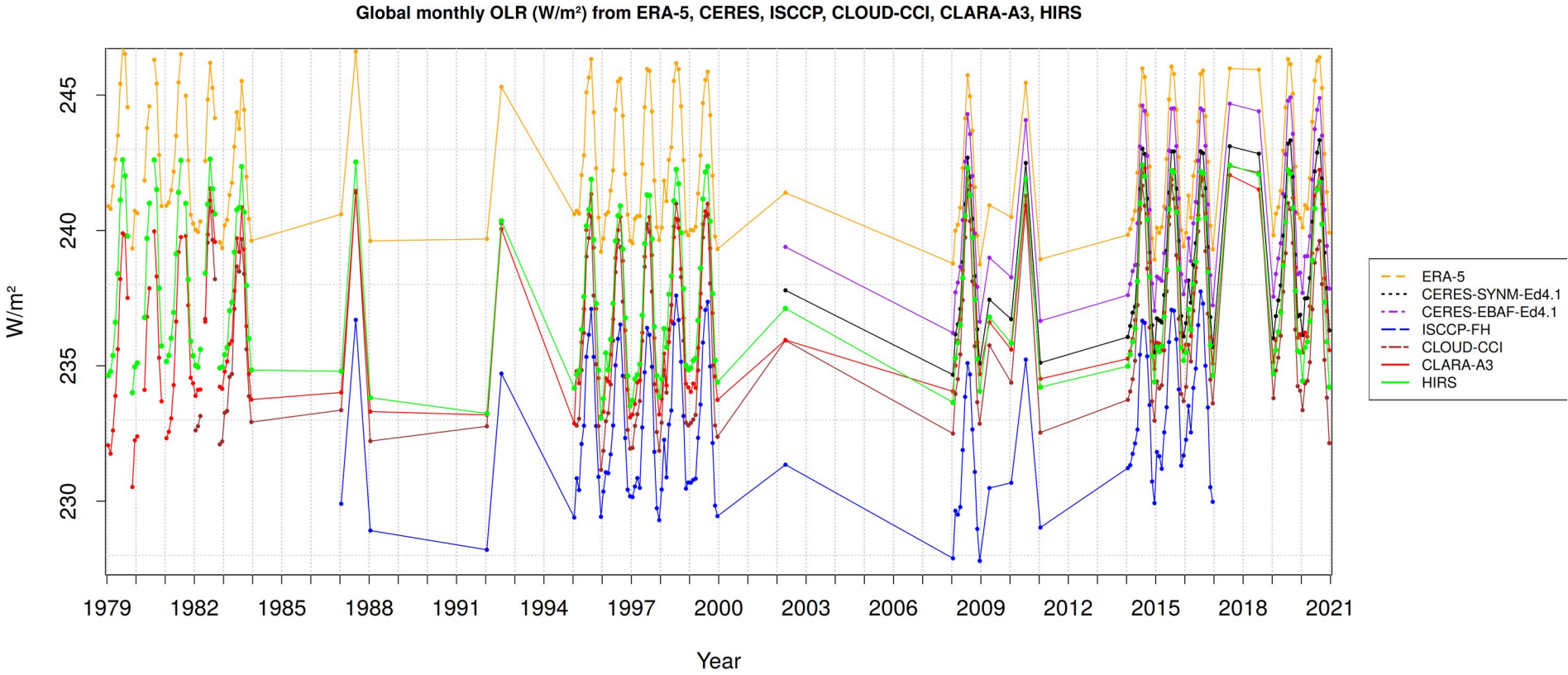
6. Extra slides

- Monthly Mean OLR for several data records:



6. Extra slides

- Monthly Mean RSF for several data records: